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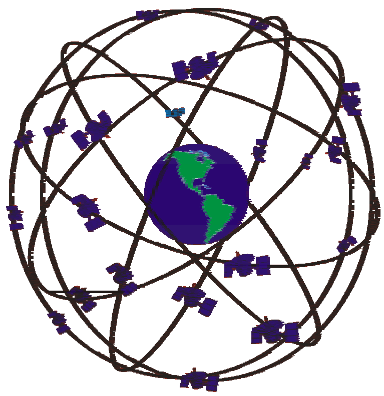
GLOBAL POSITIONING SYSTEM TEST AND EVALUATION CENTER OF EXPERTISE



GLOBAL POSITIONING SYSTEM (GPS) RECEIVER CORE TEST PLAN

Distribution A. Approved for public release. Distribution unlimited.

This document was developed by the members of the GPS Test Center of Expertise for the GPS Joint Program Office to be used to test GPS user equipment developed for DoD applications.

PREFACE

This Core Test Plan (CTP) is one of a family of Core Test Plans (CTPs) issued under the authority of the Global Positioning System (GPS) Joint Program Office. These CTPs describe the core test methodology, test beds, test methods, and analysis methods required to characterize and verify the performance of GPS receivers, Inertial Navigation Systems (INS), and integrated GPS/INS systems. Additional Test Item categories, such as Handheld GPS, integrated Doppler/GPS, and GPS antennas, and additional test methodologies such as shipboard testing, may be issued in the future.

The primary GPS test organization for the Department of Defense (DoD) consists of a number of Test Agencies from the various military Services, organized into a Center of Expertise (COE), with each of the member Test Agencies having unique test capabilities. In supporting the GPS Joint Program Office by testing DoD GPS receivers, the COE provides effective and efficient testing while minimizing duplication of testing. The Test Agencies currently included in the COE are:

Responsible Test Organization (RTO) - 46th Test Group, 746th Test Squadron

Participating Test Organization (PTO) - Space and Naval Warfare Systems Center (SPAWAR SC-SD)

PTO - U.S. Army Electronic Proving Ground (EPG)

PTO - Naval Research Laboratory (NRL)

PTO - U. S. Army Yuma Proving Grounds (YPG)

PTO - Naval Air Warfare Center – Weapons Division (NAWC-WD)

PTO - US Army Communications - Electronics Command (CECOM); Command and Control Directorate (C2D)

The COE provides a comprehensive spectrum of laboratory, van, and flight test beds to satisfy customer test requirements. A variety of precision reference systems producing very accurate Time Space Position Information (TSPI) is employed to support accurate performance evaluations.

A non-COE user of these CTPs should understand that there might be areas where the scope and terminology of a CTP are not completely applicable, especially in the testing of equipment intended for commercial application. There also may be differences in design, in which all functions or capabilities described in a CTP do not exist in the item being tested. Also, it is likely that a user's test program may be much more limited than one conducted by the DoD. In all cases, it is the responsibility of the tester to select a subset of the included tests to meet the needs of his/her test program, as well as the development of additional tests to meet specific design criteria or applications. As a minimum, these CTPs serve as a guide for developing detailed test plans for testing functions and performance areas of a particular Test Item.

ACRONYMS

AC	Alternating Current
AFMC	Air Force Material Command
BARO	Barometric
BIT	Built In Test
C/A-code	Clear/Access Code
C/No	Carrier to Noise Ratio
CDU	Control Display Unit
COE	Center of Expertise
CTP	Core Test Plan
CVw	Crypto Variable Weekly
DoD	Department of Defense
DOP	Dilution Of Precision
DTD	Data Transfer Device
EHE	Estimated Horizontal Error
FOM	Figure of Merit
GDOP	Geometric Dilution of Precision
GPS	Global Positioning System
GR	GPS Receiver
GUV	Group Unique Variable
HDOP	Horizontal Dilution of Precision
Hz	Hertz (Frequency)
ICD	Interface Control Document
INS	Inertial Navigation System
IP	Instrumentation Port
JPO	GPS Joint Program Office
MGRS	Military Grid Reference System
PC	Personal Computer
P-code	Precise code
PTTI	Precision Time and Time Interval
PPS	Pulse Per Second
PTO	Participating Test Organization
PVT	Position, Velocity, and Time

REAC	Reaction Time
REACQ	Reacquisition Time
RF	Radio Frequency
RFI	RF Interference
RTO	Responsible Test Organization
SA	Selective Availability
SEP	Spherical Error Probable
SV	Satellite Vehicle
TFOM	Time Figure Of Merit
TSPI	Time-Space-Positioning-Information
TTFF	Time To First Fix
URA	User Range Accuracy
USNO	United States Naval Observatory
UTC	Universal Time Coordinated
Vdc	Voltage DC
WGS	World Geodectic System
Y-code	encrypted P-code

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INTRODUCTION

PURPOSE

The GPS Receiver Core Test Plan (CTP) has been developed to satisfy a number of needs. First, it serves as a reference document for the DoD Test Agencies that make up the Global Positioning System (GPS) Center of Expertise (COE), so that a baseline level of agreement will exist whenever a multi-agency GPS test program is undertaken. Second, it is available for distribution to COE customers, to provide an overview of the type and level of testing available and recommended. Third, it is intended to be distributed freely to all agencies that acquire GPS systems, to be a reference document for the development of individual Test Plans. Fourth, it serves as a training document for newly assigned test engineers at the various Test Agencies.

BACKGROUND

The nature and scope of any test program is derived from the test program's purpose and the Test Item type. This CTP describes the recommended testing to achieve a thorough evaluation of GPS systems, typical of that conducted by DoD agencies. This CTP also discusses test beds, reference systems, test methods, and analytical methods associated with various test program categories and Test Item types.

AUTHORITY

The Air Force Materiel Command (AFMC) has designated the 46th Test Group, 746 Test Squadron as the Responsible Test Organization (RTO) for NAVSTAR GPS User Equipment effective 1 October 1991. Participating Test Organizations (PTOs), through the RTO, will conduct testing of GPS User Equipment for the NAVSTAR GPS Joint Program Office (JPO). The roles and responsibilities of the JPO, RTO, and PTOs are specified in Air Force Instruction 99-101.

TEST PROGRAM CATEGORIES

Within the DoD, test programs are generally categorized by the intent of the testing and the use to which the results will be put. The distinction within the categories also includes the type of source documentation against which the Test Item is evaluated as well as the rigor of the evaluation. These test program categories are generally defined as follows:

A. Certification - An extensive assessment of a Test Item's compliance with a design and/or performance specification. The test program must be sufficient to support a recommendation on the Test Item's readiness for milestones such as limited or full rate production or operational use, with results presented at a prescribed level of confidence.

B. Performance Verification - An assessment of the Test Item's compliance with a selected subset of design and performance specifications. Specification compliance must be evaluated with a prescribed level of confidence.

C. Source Selection - The acquisition and interpretation of sufficient functional and performance data to support a source selection decision. Selection criteria may include performance specifications, capability estimates, or other designated criteria.

D. Concept Demonstration - A demonstration of the viability of a Test Item design or concept.

TEST CONSIDERATIONS

Over the course of twenty years of testing GPS receivers (GRs) and systems, the GPS JPO and its test agencies have developed, usually by trial and error, an extensive technical legacy that is not easily transferred to a newcomer. This section mentions a number of considerations, in no particular order, that should be reviewed and understood before testing begins. Doing so might just eliminate a problem, and minimize the need to retest.

- GPS Simulators. A GPS simulator can be a very effective and powerful tool for both testing a GR and evaluating functionality and performance. However, its applicability to specific testing must be well-understood. The use of a simulator to determine the GRs accuracy and other performance measures is possible, depending on how the GR specification is written. A simulator usually employs models to produce a signal-in-space similar to the real world. These models include ionospheric effects, tropospheric effects, and Selective Availability. How well the simulator characterizes the real world will determine the applicability of the performance determinations.

Also, a very basic question must be answered with regard to the assumed, implied, or specified background sky noise temperature. Differences in interpretation can result in a difference in measurements of minimal signal detection and/or tracking of several dB.

Consideration must also be given to a simulator's ability to replicate the true GPS RF environment. Since it is now possible to have 11 to 14 Space Vehicles (SVs) visible at one time, it must be asked if a simulator with fewer channels adequately stresses a GRs radio frequency (RF) "front-end". If the GR under test is to be aided by Inertial Navigation System (INS), barometric (BARO), Doppler or other sources, the tester must decide if the signal provided is to be "error-free" or if it will be degraded to approximate a real-world aiding source. From experience, it does not appear that such a difference in the aiding input will cause a significant change in a GRs output, but a tester must consider the validity of testing if other than real world aiding is provided.

Annex A provides a detailed test plan for conducting <u>one</u> particular test of a GPS receiver using a GPS simulator. This test plan is provided as an <u>example</u> of configuring a simulator for this one test only, and is not intended to be directive for the tests in this document. Annex C provides examples of various dynamic scenarios which may be of use to some testers, along with reference to various supporting information and data.

- Security Considerations. This CTP is primarily intended to address the testing of authorized receivers, namely those that are capable of receiving the encrypted Y-code. Accordingly, it is recommended that all performance tests be conducted with the receiver properly keyed, and that a subset of the performance tests be conducted unkeyed, to ensure that the receiver is capable of operating with C/A code, as is almost always a requirement. Selected tests from the Laboratory Performance portion of this CTP are so marked. An authorized receiver should be simulator tested over the full range of possible signal degradation that can be applied to the signal-in-space. The tester must be fully cognizant of all security policies, both for simulator and field testing.

- Test Assumptions. The CTPs assume that a complete program of manufacturer's in-plant testing has already been satisfactorily completed, and it is strongly recommended the user review the contractor's test results before starting a program of independent testing. Accordingly, the CTPs do not address low-level testing such as Software Verification and Validation.

When testing the ability of a GR to function under stresses, such as jamming or signal loss, it is often necessary that the GR be first in a "stable" tracking condition. This condition of stability would presumably also include sufficient time for the Kalman filter to purge itself of start-up values. This data would probably only be available from the GR manufacturer.

A GR may only meet a manufacturer's claims when used with an antenna of his specifications. Substitution of another antenna may significantly impact performance. Antenna location for field tests must be chosen carefully to avoid shadowing, multipath, and, in the case of helicopter testing, rotor blade modulation.

This CTP does not provide details of operating conditions, such as dynamics associated with Acquisition Time Performance tests. These are determined by the specification, or derived from system requirements documents.

The statistics used to evaluate and report performance should be well defined before testing begins. For example, there are at least three known methods used to calculate Spherical Error Probable (SEP), all of which result in different measures.

GR output data is frequently monitored on a data bus different from the one used in its intended application, such as the RS-422 versus the MIL-STD 1553. Testing should ensure that the GR is generating the same data, with the same or comparable latency, on both busses.

This CTP addresses basic laboratory and field jamming testing. Additional testing, possibly including smart jamming, is beyond the scope of this CTP and may be classified, but should be considered by the Test Director, depending on the intended application of the Test Item.

- Data Analysis and Reporting Considerations. The data collected and reported from testing should be in a form that easily supports understanding by the targeted readers of the report and assists in determining conclusions to be derived from the test results. Essential to this is the measurement units in which the data are reported. Since different measurement units are applicable to different users and programs, this CTP will not mandate units to be used. <u>However, for tests conducted by members of the DoD Center of Expertise (COE), data will be reported in the units used in the Test Item's requirements or compliance document for the particular test program.</u> This could be the specification, Operational Requirements Document, Interface Control Document or other documentation. The use of these standard measurement units will allow easy comparison of data and results between two or more test agencies, and will allow simple evaluation of results against the test requirements.

Analysis of the functionality of a GR is a relatively straightforward process for a test agency. The questions to be addressed are answered with binary, yes/no answers, and the truth source is from a deterministic universe. e.g. A GR either has a functioning Built In Test (BIT) or it doesn't. When issues of performance must be addressed, the process becomes more complicated. GPS receivers usually have performance requirements for position, velocity, and time similar to many other navigation sensors, but the GR's ability to meet these requirements is dependent on the performance of the GPS satellite constellation.

The GPS satellite constellation (including the effects of the Control Segment) has requirements for the availability of the signal-in-space as well as the accuracy of this signal. These requirements are defined on the basis of the entire constellation, and for a sampling period of 24 hours. More specifically, the specification requirements for the GPS signal-in-space are such that a normally functioning GR is able to compute position, velocity, and time accurately 95% of the time. Thus, the signal-in-space, which is the only source from which the GR can calculate its solution, is not a deterministic source.

Therefore, it is possible for a perfectly functioning GR to output a navigation solution that fails to meet specification requirements 5% of the time, and that 5% need not be a contiguous block of 72 minutes/day (60 minutes/hour x 24 hours/day x 5% = 72 minutes/day). If a test is conducted during a time period when the constellation is producing its allowable large errors, the GR can appear to fail. A complete understanding of the variable nature of the signal-in-space is necessary for a test agency to understand what may appear to be anomalous results. (The constellation accuracy numbers are actually conditioned on the Coverage, Service Availability, and Service Reliability Standards of the system, slightly reducing the 95% requirement.)

There are a number of methods that can be used to identify or mitigate this effect. First, if the testing is to be conducted on a satellite constellation simulator, the constellation can be modified to output a deterministic signal, which will reduce the overall error budget by the amount allocated to the constellation and the Control Segment. This induces other artificialities into the results, and must be used with caution. Second, testing can be conducted over an entire 24-hour period, and the results allowed to exceed requirements 5% of the time. Thirdly, a "known-accurate" GR can be tested simultaneously, and used to validate the existence of an "adequate" signal. Where possible, the use of a "known accurate" or "reference" receiver is recommended. It is important that a test agency fully understand this concept in both designing tests and analyzing their results. The reader is encouraged to thoroughly review the "Global Positioning System Standard Positioning Service Signal Specification" issued by the Assistant Secretary of Defense, as an authoritative source for this information.

The number of test samples or tests is not specified in this Volume. Differences in application and criticality, as well as national and service requirements will affect this test consideration. Testers should consult their applicable source documents, such as Air Standard 70/11 or ASCC/NATO, to determine this requirement. Annex B provides some background in statistical significance to help the tester determine the number of test repetitions that should be performed.

GPS RECEIVER CORE TEST PLAN

The GPS Receiver Core Test Plan (CTP) presents a list of laboratory and field tests that will evaluate a GPS receiver for functionality and performance. The type of GPS receiver that this CTP addresses is a circuit card or box intended for land-mobile or airborne application, but one not integrated with an INS. The tests herein are only partially applicable to handheld GRs due to input/output and possible data monitoring restrictions. It is planned that another CTP that addresses handheld GR testing will be produced in the future. Integrated GPS/INS are addressed in the Integrated GPS/INS CTP. Generally, the tests included in this CTP are not repeated in that CTP, so both must be used to develop test plans for integrated GPS/INS systems. It is strongly recommended that the Introduction to this CTP be read and understood before developing a test plan from this CTP.

Each test contains four sections. They are: the Test Objective(s), Special Test Equipment, Test Methods, and Data Collection and Analysis Methods. Related definitions and/or test philosophy are included where necessary to provide clarification. No attempt has been made to combine tests for maximum efficiency.

This CTP follows the test philosophy of "crawl, walk, run", in that the quickest, cheapest, most controlled tests are performed first. These would include laboratory tests, mobile field tests in a basic vehicle ("van"), and then flight tests. This allows for a slow development of information pertaining to the Test Item, and employs the least expensive test methodology first. The "van" testing allows for the functional check of the installation/integration package, and initial field testing with dynamics, vibration, and temperature variances. Van testing can also be considered representative of the conditions experienced in any land vehicle and can be tailored to address specific performance requirements. The problem with field testing, apart from the high cost, is the potential lack of control of the test conditions and a lack of repeatability. The philosophy adopted for this CTP is to conduct field testing because: (1) the test cannot be conducted in the laboratory, (2) it is necessary to validate laboratory results as applicable to the real world, and (3) it is necessary to demonstrate the field capability of the Test Item. Within the series of flight tests, a similar philosophy is adopted, conducting as much testing as possible on a "cargo" type aircraft, which is relatively easy to access and instrument, and inexpensive to operate. Only specific tests within the unique flight regimes of the "fighter" and the "helicopter" are included in their respective areas. For any particular test program, the Test Director will evaluate his available assets and determine the most practical and cost-efficient way to accomplish the required test program.

1. <u>INITIAL CHECKOUT</u>

These tests, replicated in each CTP, identify laboratory events to be conducted on every category of Test Item.

1.1. Configuration Verification.

This test is designed to ensure that the Test Item conforms to its identification, size, and weight requirements; appears secure enough to withstand testing; and has its ancillary and support equipment as needed for the envisioned test program. The configuration of the test site's test equipment will also be identified.

1.1.1. Test Objectives.

The test objectives are to verify the Test Item physical requirements and to initiate hardware and software configuration control.

1.1.2. Special Test Equipment.

None required.

1.1.3. Test Methods.

An audit of hardware and software assets will be performed upon delivery of each Test Item. The audit will gather, as a minimum, the following information:

A. Part and Serial Number(s) sufficient to provide Configuration Management
B. Software Version
C. Elapsed Time Reading
D. Size and Weight
E. Primary Power
F. Interfaces
G. Visual inspections of workmanship
H. Required Equipment Checklist.
I. Laboratory test equipment, including calibration date(s)
J. Laboratory test software version numbers

1.1.4. Data Collection and Analysis Methods.

Data will be reported in the measurement units of the requirements document. The weight, size, part numbers, serial numbers, and software version will be compared with configuration identification information provided by the manufacturer. Any discrepancies will be resolved.

1.2. Power-on Safety.

1.2.1 Test Objectives.

The test objective is to verify the safety of the test personnel, the laboratory equipment, and the Test Item, prior to the initial application of power.

1.2.2. Special Test Equipment.
None required.

1.2.3. Test Methods.
Each power, data, and RF connector of the Test Item will be identified and matched to its appropriate counterpart in the laboratory. Test personnel will verify:

A. the correct power connector is used,
B. the supplied voltage and frequency (AC circuits) matches the manufacturer's requirements,
C. there is adequate circuit protection,
D. the circuit impedance is correct (RF circuits).

Data connectors will be matched to the appropriate connector on laboratory equipment. Test personnel will take precautions to guard against static electricity damage. Leakage current will be measured on all exposed portions of the Test Item.

1.2.4. Data Collection and Analysis Methods.
The manufacturer's documentation will be reviewed to ensure that each connection matches the configuration of the laboratory.

The remainder of this CTP identifies GPS Receiver (GR) laboratory, van, and flight tests; and describes test objectives, special test equipment, test methods, and data collection and analysis methods. Paragraphs 2.X present laboratory tests, paragraphs 3.X present van tests, and paragraphs 4.X present flight tests.

2. LABORATORY

Table 1 identifies the test objective, responsible test, and CTP paragraph for each test objective of this section. These tests are separated into Functional and Performance test objectives.

Table 1. GR Laboratory Tests

Test Objective	Responsible Test	CTP Test Paragraph
Functional Tests		
Demonstrate acceptable:		
Signal Interfaces Operation:		
MIL-STD 1553B	GR MIL-STD 1553B	2.1.1.
Data Transfer Device (DTD)	DTD Compatibility	2.1.2.
Instrumentation Port RS-422	IP RS-422	2.1.3.
ARINC-429	ARINC-429	2.1.4.
Precise Time and Time Interval (PTTI)/Havequick	PTTI/Havequick	2.1.5.
Radio Frequency (RF) Signal & Antenna Interface	RF Signal and Antenna Interface	2.1.6.
Lab GPS Navigation Operation	GR Static Navigation	2.1.7.
Maintenance of Non Volatile Data	Maintenance of Non Volatile Data	2.1.8.
Position, Velocity and Time (PVT) Solution Rates	PVT Solution Rates	2.1.9.
Satellite Selection	Satellite Selection	2.1.10.
Carrier to Noise (C/No) Estimation	C/No	2.1.11.
Coordinate Systems Function	Coordinate Systems	2.1.12.
Built In Test (BIT) Operation	BIT	2.1.13.
Waypoint Navigation	Waypoint Navigation	2.1.14.
Performance Tests		
Evaluate:		
Navigation Accuracy	GR Navigation Solution and Time	2.2.1.
1 Pulse Per Second Calibration	1PPS Calibration	2.2.2.
Acquisition Time	Acquisition Time Performance	2.2.3.
Figure of Merit (FOM)	FOM	2.2.4.
Degraded GPS/Baro Aiding	Degraded GPS/Baro Aiding	2.2.5.
Multipath	Multipath Characterization	2.2.6
RF Interference (RFI)/Jamming	GR Jamming	2.2.7.
Stability	Long Duration Stability	2.2.8.

2.1. Functional Tests.

2.1.1. GR MIL-STD-1553B.

2.1.1.1. Test Objective.

The test objective is to demonstrate that the Test Item responds correctly to received MIL-STD 1553B messages and transmits correct MIL-STD 1553B output messages. The test verifies the following operations under MIL-STD 1553B bus control:

A. Acceptance of lever arm coordinates
B. Acceptance of baro altimeter aiding
C. Acceptance of magnetic variation coefficients
D. Acceptance of cryptovariables
E. Acceptance of waypoints via the data loader 1553 message
F. Acceptance of datum initialization
G. Acceptance of time, latitude and longitude updates
H. Initialization of the GR functions
I. Transition into and between all modes
J. Correct formatting and performance of the instrumentation interface as described in the contractor documentation and in accordance with ICD GPS-059 or ICD GPS-151
K. Appropriate solution(s) availability during each mode of navigation operation

2.1.1.2. Special Test Equipment.

A. Either a GPS simulator or a GPS antenna
B. 1553 bus controller

2.1.1.3. Test Methods.

A. Simulator Configuration - Live or simulated satellite vehicle (SV) signals will be provided to the Test Item for this test. If used, the simulator will be configured to provide a nominal constellation with the Test Item remaining in a static condition. For additional background information about simulator configuration and operation, see Annex A.
B. Test Execution - The Test Item will be initialized and allowed to acquire at least four SVs with FOM<3. An external bus controller will send Test Item input messages to exercise Test Item mode controls and monitor Test Item output messages for the appropriate mode changes and data responses. The following Test Item modes will be enabled, verified, and then disabled:
    1) Baro altitude aiding
    2) Lever arm corrections
    3) Altitude hold
    3) BIT

Proper acceptance of cryptovariables and waypoints will be verified. The Test Item will be sent time and position updates and the data checked to ensure acceptance. Various datums will be sent to the Test Item and the output checked to ensure acceptance and transition. The Test Item MIL-STD 1553B and Instrumentation Port (IP) messages will be recorded. Magnetic variation data values and coefficients will be sent to the Test Item and horizontal angular quantities based on true and magnetic north will be recorded.

2.1.1.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Simulator identification and scenario configuration.
Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, Estimated Horizontal Error (EHE), etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. The proper acceptance and disposition of all initialization parameters will be verified. Mode transitions and proper indication of modes via the MIL-STD 1553B bus will be verified. All message formats will be reviewed to verify consistency with contractor documentation and applicable specifications. SV acquisition and time to first fix (TTFF) will be noted and the generation of reasonable Test Item navigation solutions will be verified. Correction for magnetic variation will be verified.

2.1.2. Data Transfer Device (DTD) Compatibility.

{See GPS Receiver CTP Addendum (Distribution C)}

2.1.2.1. Test Objective.

The test objective is to verify the following functions.

A. Crypto Variable (CV) CV weekly (CVw) and Group Unique Variable (GUV)) management functions.
B. Related input/output interface communications.
C. Critical security functions.

2.1.2.2. Special Test Equipment.

A. GPS simulator
B. All DTDs specified for use with the Test Item
C. Actual and simulator crypto
D. 1553 bus monitor

2.1.2.3. Test Methods.

It is recommended that this test be conducted with a simulator, using simulator keys.

A. Simulator Configuration – The simulator will be configured to provide a nominal constellation with the Test Item remaining in a static condition. For additional background information about simulator configuration and operation, see Annex A.

B. Reserved.

2.1.2.4. Data Collection and Analysis Methods.
As a minimum, test relevant data will be collected and recorded as follows:

Simulator identification and scenario configuration.
Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.
Visual display indications.
Displayed messages.

Data will be reported in the measurement units of the requirements document.

2.1.3. IP RS-422.

2.1.3.1. Test Objective.
The test objective is to verify that the Instrumentation Port (IP) RS-422 data block formats conform to the correspondent IP ICD, such as ICD GPS-150, ICD GPS-153, etc.

2.1.3.2. Special Test Equipment.
A GPS simulator or GPS antenna is required for this test.

2.1.3.3. Test Methods.
A. Simulator Configuration – Live or simulated satellite vehicle (SV) signals will be provided to the Test Item for this test. If used, the simulator will be configured to provide a nominal constellation with the Test Item remaining in a static condition. For additional background information about simulator configuration and operation, see Annex A.

B. Test Execution - The Test Item will be interfaced to a PC buffer box via the RS-422 port. The Test Item will be powered on, initialized, and placed in Navigate mode. The data block will be enabled and recorded.

2.1.3.4. Data Collection and Analysis Methods.
As a minimum, test relevant data will be collected and recorded as follows:

Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. The PC buffer box output will be monitored in real time and the data recorded for post test analysis to verify the data block formats conform to the correspondent IP ICD, such as ICD GPS-150, ICD GPS-153, etc.

2.1.4. ARINC-429.

2.1.4.1. Test Objective.

The test objective is to verify that the Test Item will interface with a low speed serial data output bus (ARINC-429) providing the host vehicle flight instruments with GPS navigation data.

2.1.4.2. Special Test Equipment.

A GPS simulator or GPS antenna, and an ARINC-429 interface card are required for this test.

2.1.4.3. Test Methods.

A. Simulator Configuration - Live or simulated satellite vehicle (SV) signals will be provided to the Test Item for this test. If used, the simulator will be configured to provide a nominal constellation with the Test Item remaining in a static condition. For additional background information about simulator configuration and operation, see Annex A.

B. Test Execution - The ARINC-429 data will be recorded and displayed on a personal computer, using a 429 card. The Test Item will be powered on, initialized, and placed in Navigate mode. The data block will be enabled and recorded.

2.1.4.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B, ARINC-429, and IP data.

Data will be reported in the measurement units of the requirements document. The ARINC-429 flight instrumentation data will be compared to the data formats called out in ICD GPS-073.

2.1.5. PTTI/Havequick.

2.1.5.1. Test Objective.

The test objective is to verify the Test Item precise time and time interval (PTTI) interface is capable of transferring precise time. The test verifies the 1PPS and Havequick signal voltage levels and data format conformance with ICD GPS-150, ICD GPS-060 or other appropriate ICDs

2.1.5.2. Special Test Equipment.

A GPS simulator or GPS antenna is required for this test.

2.1.5.3. Test Methods.

A. Simulator Configuration - Live or simulated satellite vehicle (SV) signals will be provided to the Test Item for this test. If used, the simulator will be configured to provide a nominal constellation with the Test Item remaining in a static condition. For additional background information about simulator configuration and operation, see Annex A.

B. Test Execution - The Test Item will be operated in the Navigation mode. The Test Item 1PPS output will be verified against a reference 1PPS signal with a time interval counter. A logic analyzer, storage oscilloscope, or other laboratory test equipment triggered by the Test Item 1PPS signal will be used to monitor the Havequick signal.

2.1.5.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.
Test Item Havequick and 1PPS output.

Data will be reported in the measurement units of the requirements document. The stability of the 1PPS signal will be verified. The Havequick message will be checked for proper voltage levels using the display of the logic analyzer. The data period of a single bit of information shall be verified. The Havequick message content will be decoded and the phasing pattern, indicator field, parity bits, and data will be verified. For both the 1PPS and Havequick signals, the signal voltage levels, pulse timing, pulse rise time, line impedance, and delay, shall meet specification values.

2.1.6. RF Signal & Antenna Interface.

2.1.6.1. Test Objective.
The test objective is to verify that the Test Item equipped with a GPS antenna can track live satellites, at all required power levels, on L1 and L2 frequencies as specified in ICD GPS-200.

2.1.6.2. Special Test Equipment.
A GPS simulator and GPS antenna are required for this test.

2.1.6.3. Test Methods.
A. Simulator Configuration - Live and simulated satellite vehicle (SV) signals will be provided to the Test Item for this test. The simulator will be configured to provide a nominal constellation with the Test Item remaining in a static condition. For additional background information about simulator configuration and operation, see Annex A.

B. This test will first be conducted with an antenna interfaced to the Test Item RF port and tracking live GPS satellites. The antenna mask angle will be set to the minimum value specified for normal operations, or if none is specified, allowed to remain at the power-on defaults. The Test Item will be initialized, keyed, switched to navigation mode, and allowed to track for 2 hours. This will allow for periods of satellite constellation switching and tracking at low elevations. The Test Item will be connected to a GPS satellite simulator and the test will be repeated, this time with the satellite signal levels being varied from the minimum specified signal level to the maximum specified signal level. A control display unit (CDU) or buffer box will be interfaced with the Test Item to monitor the C/No and tracking status.

2.1.6.4. Data Collection and Analysis Methods.
As a minimum, test relevant data will be collected and recorded as follows:

- Test equipment identification and calibration dates.
- Test Item identification.
- Test Item navigation solution and time output at 1 Hz minimum.
- Test Item health status and state or tracking codes.
- Test Item internal accuracy estimators (FOM, EHE, etc.).
- Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. Satellite C/No will be monitored to verify that received power is reported as being within specification, and that the Test Item is able to function correctly at all specified input power levels.

2.1.7. GR Static Navigation.

2.1.7.1. Test Objectives.
The test objectives are to verify that the Test Item is functioning properly in a non-dynamic environment, and to demonstrate the Test Item navigation solution is being generated and displayed.

2.1.7.2. Special Test Equipment.
A GPS simulator or GPS antenna is required for this test.

2.1.7.3. Test Methods.
A. Simulator Configuration - Live or simulated satellite vehicle (SV) signals will be provided to the Test Item for this test. If used, the simulator will be configured to provide a nominal constellation with the Test Item remaining in a static condition. For additional background information about simulator configuration and operation, see Annex A.

B. Test Execution - The basic navigation mode will be tested as well as special navigation modes (i.e., standby mode, stationary mode, etc.). The duration of the test will be at least 15 minutes for each navigation configuration/mode to ensure collection of sufficient navigation data.

2.1.7.4. Data Collection and Analysis Methods.
As a minimum, test relevant data will be collected and recorded as follows:

Simulator identification and scenario configuration.
Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. The data will be reviewed to determine that the Test Item is functioning properly. The Test Item navigation solution will be compared with the static coordinates to verify the system is operating properly.

2.1.8. Maintenance of Non-Volatile Data.

2.1.8.1. Test Objective.
The test objective is to verify that the Test Item is capable of protecting the data in the nonvolatile database against loss due to power disconnect.

2.1.8.2. Special Test Equipment.
A GPS simulator or GPS antenna is required for this test.

2.1.8.3. Test Methods.

A. Simulator Configuration - Live or simulated satellite vehicle (SV) signals will be provided to the Test Item for this test. If used, the simulator will be configured to provide a nominal constellation with the Test Item remaining in a static condition. For additional background information about simulator configuration and operation, see Annex A.

B. Test Execution - The Test Item will be turned on in navigation mode, without dynamics, and will navigate for at least 15 minutes to allow collection of complete almanac information before the power is cycled off and back on. Duration of the power off condition will be determined by the system requirements.

2.1.8.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Simulator identification and scenario configuration.
Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. Before power loss, and following power restoration, the contents of the nonvolatile database shall be examined; the integrity of the data is verified if there is no difference between the contents before and after power loss and recovery.

2.1.9. PVT Solution Rates

2.1.9.1. Test Objective.

The test objective is to determine the Test Item position, velocity, and time (PVT) solution rates in all available navigation modes in a static scenario.

2.1.9.2. Special Test Equipment.

A GPS simulator or GPS antenna is required for this test.

2.1.9.3. Test Methods.

A. Simulator Configuration - Live or simulated satellite vehicle (SV) signals will be provided to the Test Item for this test. If used, the simulator will be configured to provide a nominal constellation with the Test Item remaining in a static condition. For additional background information about simulator configuration and operation, see Annex A.

B. Test Execution - The Test Item will be turned on in navigation mode, and each navigation configuration/mode of the GPS receiver (i.e., standby mode, stationary mode, etc.) will be exercised for a minimum of 10 minutes.

2.1.9.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Simulator identification and scenario configuration.
Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. The data shall be analyzed to determine if the PVT solution rates meet specification requirements.

2.1.10. Satellite Selection.

2.1.10.1. Test Objective.

The test objective is to verify that the Test Item is capable of selecting satellites that produce a specification-compliant navigation solution:

A. When satellites are rising/setting, or experiencing changes of health and user range accuracy (URA) values
B. When an alternate satellite selection criteria strategy is used

2.1.10.2. Special Test Equipment.

A GPS simulator is required for this test.

2.1.10.3. Test Methods.

A. Simulator Configuration – The simulator will initially be configured to provide a nominal constellation. The simulator scenario should be reviewed to ensure that the Test Item will experience both rising and setting satellites and changes in satellite geometry which will exercise the Test Item's selection algorithms. For additional background information about simulator configuration and operation, see Annex A.
B. Test Execution – Both static and dynamic scenarios will be used. The Test Item will be initialized and allowed to acquire a nominal constellation. During the test, some satellites will set/rise or change health/URA values, causing the Test Item to utilize different satellite combinations. Also, the Test Item will be commanded to use a baroaltimeter measurement instead of a satellite measurement or other alternate selection criteria, if these features are available.

2.1.10.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Simulator identification and scenario configuration.

Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. The data will be analyzed to determine if the receiver selects the constellation that produces the best navigation solution, the criteria used in changing satellite selection, and the effects on the navigation solution. All data related to the number of satellites available/used, satellite health/URA, (weighted) GDOP/HDOP, and navigation solution will be recorded and analyzed.

2.1.11. C/No.

2.1.11.1. Test Objective.

The test objective is to verify that the Test Item is capable of computing/displaying a good estimate of the signal strength (i.e., carrier-to-noise ratio (C/No)) under various signal levels.

2.1.11.2. Special Test Equipment.

A GPS simulator is required for this test.

2.1.11.3. Test Methods.

A. Simulator Configuration – The simulator will initially be configured to provide a nominal constellation with the Test Item remaining in a static condition. The simulator scenario will then vary satellite power levels over a range to span the expected power levels on all applicable frequencies. For additional background information about simulator configuration and operation, see Annex A.

B. Test Execution - The Test Item will be turned on in the navigation mode and the C/No will be displayed.

2.1.11.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Simulator identification and scenario configuration.
Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.
Test Item C/No.

Data will be reported in the measurement units of the requirements document. The C/No will be observed to insure that the value is equivalent to the supplied power level, in accordance with the Test Item specification.

2.1.12. Coordinate Systems.

2.1.12.1. Test Objective.

The test objective is to verify that the Test Item displays or outputs position data in the datums and coordinate systems required by its specification, such as WGS-84, MGRS, etc.

2.1.12.2. Special Test Equipment.

A GPS simulator or GPS antenna is required for this test.

2.1.12.3. Test Methods.

A. Simulator Configuration - Live or simulated satellite vehicle (SV) signals will be provided to the Test Item for this test. If used, the simulator will be configured to provide a nominal constellation with the Test Item remaining in a static condition. For additional background information about simulator configuration and operation, see Annex A.

B. Test Execution - The Test Item will be turned on and placed in the navigation mode. Each datum and coordinate system will be selected and the position data recorded.

2.1.12.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Simulator identification and scenario configuration.
Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. During navigation operations in each coordinate system, the Test Item displays will be checked to verify that the proper indications are shown. The recorded data for each coordinate system will be compared with the static benchmark coordinates as expressed in the selected datum.

2.1.13. BIT.

2.1.13.1. Test Objective.

The test objective is to verify that the power-on, periodic, and commanded Built In Test (BIT) functions perform properly.

2.1.13.2. Special Test Equipment.

A GPS simulator or GPS antenna is required for this test.

2.1.13.3. Test Methods.

A. Simulator Configuration - Live or simulated satellite vehicle (SV) signals will be provided to the Test Item for this test. If used, the simulator will be configured to provide a nominal constellation with the Test Item remaining in a static condition. For additional background information about simulator configuration and operation, see Annex A.

B. Test Execution - The Test Item will be turned on and the operator will confirm the power-on BIT. The Test Item will be left on for at least 30 minutes and a commanded BIT will be performed every 10 minutes. Intentional fault conditions may be introduced (such as disconnecting the antenna or removal of memory back-up batteries) prior to or during testing to confirm the detection of specific malfunctions.

2.1.13.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Simulator identification and scenario configuration.
Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. The preventive maintenance fault log located in nonvolatile memory and, if available, BIT status data recorded from output ports such as the MIL-STD 1553B will be reviewed to confirm that the BIT modes are functioning.

2.1.14. Waypoint Navigation.

2.1.14.1. Test Objective.

The test objective is to ensure that the Test Item, if equipped to perform Waypoint Navigation, does so correctly.

2.1.14.2. Special Test Equipment.

A GPS simulator is required for this test.

2.1.14.3. Test Methods.

A. Simulator Configuration – The simulator will be configured to provide a nominal constellation. A dynamic scenario will be utilized to exercise the Waypoint Navigation function. For additional background information about simulator configuration and operation, see Annex A.

B. Test Execution - The maximum number of Waypoints and Routes required by the specification will be loaded into the Test Item via the MIL-STD 1553 bus. The Test Item will be commanded to calculate navigation data and output via the ARINC 429 port and/or the MIL-STD 1553 bus. At least one route will be navigated against the simulator, with any waypoint navigation errors determined from post-mission data comparison.

2.1.14.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Simulator identification and scenario configuration.
Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.)
Test Item MIL-STD 1553B and IP data

Data will be reported in the measurement units of the requirements document. The ARINC 429 and/or the MIL-STD 1553 outputs will be monitored and the IP RS-422 used to evaluate the Test Item's correct storage of input data and correct Waypoint Navigation functions. The maximum number of Waypoints and Routes stored by the Test Item will be evaluated. The route(s) navigated will be evaluated for accuracy.

2.2. Performance Evaluation.

While Functional Evaluation is usually closely controlled by product specifications, during Performance Evaluation testing the tester must determine the appropriate platform dynamic conditions and GPS satellite conditions under which to test the GR. Unless constrained by specifications, various constellations, resulting in a range of number of visible satellites and "dilution of position (DOP)" should be selected to represent the environment in which the GR will be expected to operate. The following GR laboratory tests address a GR functioning "unaided" in normal operation. If the GR has the capability to operate with barometric, Doppler, INS, clock, or other aiding, the GR should be tested with appropriate aiding. "Aiding" is defined as the use of an external source of position, velocity, or time which assists the GR in acquiring or maintaining tracking of the satellite signals, and where the external source data may or may not be included in the navigation solution. The tester must understand the GR's implementation of the aiding to understand which performance measures will be affected. Depending on the specification, it may or may not be necessary to conduct these tests with aiding disabled. Also, measurement of a GPS receiver's time calculation is important. Time bias errors are likely to exist even in a receiver with an accurate navigation solution. This is because delays in the receiver that are common to all channels do not affect the navigation solution. The receiver cannot internally determine the magnitude of delays in the antenna, antenna electronics, cables, or the analog portions of the receiver. Similarly, there are usually biases between the receiver's internal clock and the timing signal produced. Even though the measurement of the accuracy of the time output is shown during all tests where position and velocity are measured, a dedicated test for time accuracy (1PPS Calibration) is included to provide additional information on time errors, test setup, and test procedures. It is recommended that the setup for this test be employed for all similar tests to ensure that the test conditions do not induce discrepancies in the GR's time calculation.

2.2.1. GR Navigation Solution and Time.

2.2.1.1. Test Objective.

The test objective is to verify that the Test Item performs correctly under static and dynamic conditions.

2.2.1.2. Special Test Equipment.

A GPS simulator is required for this test.

2.2.1.3. Test Methods.

A. Simulator Configuration – The simulator will initially be configured to provide a nominal constellation with the Test Item remaining in a static condition. A dynamic profile that exercises the Test Item against its intended application should then be started. For additional background information about simulator configuration and operation, see Annex A. For additional information about possible dynamic scenarios, see Annex C.

B. Test Execution - The Test Item will be powered on and allowed to navigate for 1 hour or the time to collect a complete almanac and become stabilized. The Test Item will then be powered off and restarted and allowed to navigate in a simulated environment using a dynamic profile which will exercise the GR to its application limits. During the selected scenario, the Test Item should also be subjected to one or more satellite constellation changes. The navigation solution and time data will be recorded on the RS-232, RS-422, and/or MIL-STD 1553B ports. It is recommended that this test be repeated for C/A operation with the Test Item unkeyed and the simulator keyed.

2.2.1.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Simulator identification and scenario configuration.
Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. The Test Item navigation solution and time data from the MIL-STD 1553B or instrumentation port (IP) will be compared to the simulated dynamic profile. For all test configurations, the accuracy of the navigation solution and time will be determined. Particular emphasis will be placed on analyzing Test Item operation in turns, during constellation changes, and during maneuvers. Anomalous behavior will be noted.

2.2.2. 1PPS Calibration.

Time bias errors are likely to exist even in a receiver with an accurate navigation solution. This is because delays in the receiver that are common to all channels do not affect the navigation solution. The receiver cannot internally determine the magnitude of delays in the antenna, antenna electronics, cables, or in the analog portions of the receiver. In addition, there are usually biases between the receiver’s internal clock and the output timing signal. They may be simple cable length delays but can also include random delays inherent in the process of creating an output of one pulse per second (1 PPS) or a time code. The error in the time output of a GPS receiver can be determined either using a GPS signal simulator or live satellites. In order to measure the time output of the receiver, an accurate time reference signal is required. For simulator tests, this can be the 1 PPS output signal from the simulator. Although there is usually bias between the simulator 1 PPS and the simulator RF output signal, this bias can be measured and corrected. The procedure for this is unique to the simulator being used. For testing with live satellites, the tester would need an accurate source of UTC(USNO), the time broadcast by the GPS satellites.

2.2.2.1. Test Objective.

The test objective is to determine the absolute accuracy of the 1PPS and/or time code output.

2.2.2.2. Special Test Equipment.

A GPS simulator or GPS antenna is required for this test. An accurate time reference is also required.

2.2.2.3. Test Methods.

A. Simulator Configuration – The simulator will be configured to provide a nominal constellation with the Test Item remaining in a static condition. For more detail about simulator configuration, see Annex A.

Figure 1 shows a typical hardware configuration for measuring the receiver timing error.

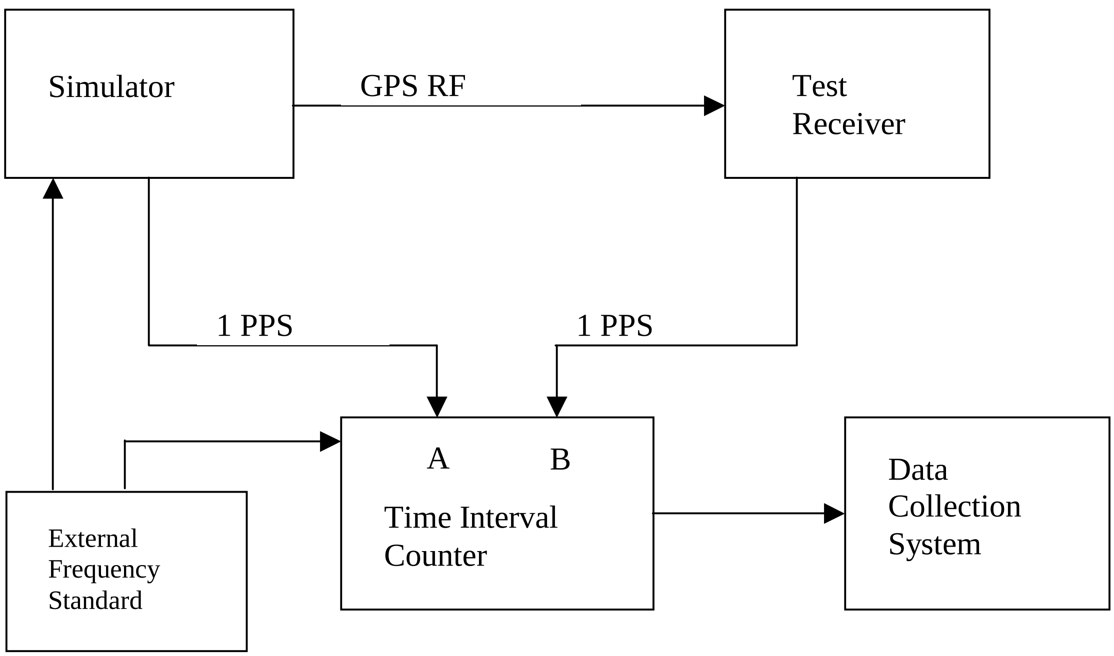


Figure 1. Test configuration.

In this configuration, the reading on the time interval counter will be the time difference between the simulator and the receiver under test. It is desirable to operate the counter and the simulator from the same frequency reference. If the counter's internal oscillator is off frequency, the time interval reading will also be in error, particularly for larger time offsets.

B. Test Execution – The Test Item will be switched to navigation mode and operated normally. A time interval counter will be used to measure the time between the simulator's 1PPS reference and the corresponding Test Item 1PPS signal output. During the test, the time interval counter will be monitored to detect gross jitter in the Test Item timing signal. For those receivers that output time rather than a 1PPS signal, the test will be conducted in a similar fashion except the difference in reference time and Test Item time will be monitored. This same method can be used for live testing. The difference will be that the on-time reference 1 PPS to the time interval counter must come from a good source of UTC. This could be another GPS receiver of known calibration or a synchronized external clock. Most commercial counters that make time interval readings will be adequate. The high stability oscillator option in one of these counters is not required since an external reference is used. Even the high performance internal clocks are not accurate enough for making 1 nsec resolution readings on 1-second intervals.

Notes:

1. Time interval counter trigger levels set at 1 volt, DC coupled, 50 ohm impedance
2. Cables between devices and counter must be matched or calibrated
3. The delay in the cable from the simulator to the receiver must be calibrated
4. Internal delay in the simulator between the 1 PPS signal and the RF code cycle must be calibrated. In the GSS simulators, this is typically around 100 nsec. See the detailed procedure for the particular simulator in use.
5. If the receiver pulse is ahead of the simulator pulse, the counter may read a number as large as one second when the true offset is a small negative number. Some counters will correct this internally and display the negative number. If not, reverse the input leads and treat the answer as negative.

2.2.2.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Simulator identification and scenario configuration.
Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.
Simulator and Test Item 1PPS signals.

Data will be reported in the measurement units of the requirements document. The recorded time intervals will be plotted and analyzed to verify that the time difference does not exceed specification. Statistics characterizing the difference will be calculated.

2.2.3. Acquisition Time Performance.

Since the development of the GPS system, a number of parameters have been used to define the amount of time needed for a GPS receiver to develop or reestablish a valid navigation solution, given various initial conditions and uncertainties. Some of these conditions and uncertainties include:

A. Whether the receiver has current almanac, satellite health, and current ephemeris in memory
B. Initial receiver position, velocity, and time errors
C. Aiding, or lack thereof
D. Time required for warmup of the receiver's internal oscillator
E. If the receiver is capable of direct-Y acquisition
F. The amount of time since the receiver lost contact with one or more satellites

These parameters have been variously known as: Time-To-First-Fix (TTFF), Reaction Time (REAC), Reacquisition Time (REACQ), Hot Start, Cold Start, Warm Start, and various other names. These parameters are NOT specified for the GPS system, but are part of individual GPS receiver specifications. Over time, various definitions, as well as various initial conditions and uncertainties have been applied to these parameters. Thus, it is now impossible to create a test using any of these parameter names without the test being specific to only one or two GPS receivers. This test, titled Acquisition Time Performance was developed to define, at the broadest level, the nature of this type of testing. For any particular GPS receiver, one or more tests must be created to evaluate that receiver's ability to acquire and track satellites and develop a valid navigation solution, within the times as delineated in its specification.

2.2.3.1. Test Objective.

The test objective is to verify that the Test Item provides navigation data within specified time requirements, given specified initial conditions and uncertainties.

2.2.3.2. Special Test Equipment.

A GPS simulator is required for this test.

2.2.3.3. Test Methods.

A. Simulator Configuration – The simulator will be configured to provide a constellation representative of the minimal conditions required by the specification. The dynamic conditions and aiding defined by the specification will be simulated. For additional background information about simulator configuration and operation, see Annex A.
B. Test Execution – The Test Item will be configured in accordance with its specification. If critical memory is to be erased, the manufacturers recommended methods must be used to avoid unintentionally affecting other areas of the set. After the receiver has indicated achieving a successful signal reacquisition or navigation solution, it will be allowed to navigate for about 10 minutes to allow the collection of sufficient data for evaluation.

2.2.3.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Simulator identification and scenario configuration.
Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. The Test Item data will be processed and analyzed to verify navigation and time accuracy. The data will be examined to verify that the Test Item has successfully met its specification performance requirements. See 2.2.2 for details of time testing.

2.2.4. FOM.

2.2.4.1. Test Objectives.

The test objectives are to verify that the Test Item FOM and Time Figure of Merit (TFOM) are calculated as required by the specification and that the Test Item uses appropriate SV selection strategies.

2.2.4.2. Special Test Equipment.

A GPS simulator is required for this test.

2.2.4.3. Test Methods.

A. Simulator Configuration – The simulator will initially be configured to provide a nominal constellation with the Test Item remaining in a static condition. SV geometry shall then be set to produce a temporary GDOP hole where the GDOP shall be at least 300 for a period of 20 minutes. The poor satellite geometry will result in a navigation solution that slowly degrades with time. Other tests to verify TFOM and FOM will include dropping to three satellites for 20 minutes and setting the user range accuracy (URA) in the navigation message to a high value. For additional background information about simulator configuration and operation, see Annex A.

B. Test Execution - The Test Item shall be initialized and then commanded into the navigation mode. The MIL-STD-1553B, RS-422, and/or RS-232 port navigation data will be recorded. It is recommended that this test be repeated for C/A operation with the Test Item unkeyed and the simulator keyed.

2.2.4.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Simulator identification and scenario configuration.
Test equipment identification and calibration dates.
Test Item identification.

Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. The Test Item data will be processed and analyzed to verify navigation accuracy. The navigation error and the FOM and TFOM will be analyzed to evaluate if the FOM and TFOM reflect the true error, as required by the specification, for each degraded case tested. The analysis shall verify that the TFOM and FOM reflect the effects of SV geometry when GDOP is very large, when there are fewer than four satellites, and when URA is set high. Similar analysis may be performed on data gathered from the conduct of other laboratory tests. See 2.2.2 for details of time testing.

2.2.5. Degraded GPS/Baro Aiding.

2.2.5.1. Test Objectives.

The test objectives are to verify the Test Item operation:

A. In the event that fewer than four satellites are tracked
B. Under the conditions of degraded performance (which includes three satellite/altitude hold mode) and to verify satisfactory operation of the baro aiding function.

2.2.5.2. Special Test Equipment.

A GPS simulator is required for this test.

2.2.5.3. Test Methods.

A. Simulator Configuration – The simulator will initially be configured to provide a four-satellite constellation. Both static and dynamic scenarios will be used. The simulator must be capable of providing baro aiding. After at least 10 minutes of stable navigation with baro aiding, the constellation/simulator will be configured as follows, for intervals of at least 5 minutes per condition:
   1) four satellite navigation with baro aiding,
   2) three satellite navigation with baro aiding,
   3) three satellite navigation without baro aiding,
   4) two satellite navigation without baro aiding,

   An interval of stable, four satellite navigation with baro aiding of at least 10 minutes should occur between each repetition of these four conditions. For additional background information about simulator configuration and operation, see Annex A.
B. Test Execution - The Test Item will be turned on in the navigation mode, and allowed to acquire a stable navigation solution. The Test Item will then be subjected to the scenario as described above. Navigation data will be recorded on the MIL-STD 1553B, RS-422, and/or RS-232 ports.

2.2.5.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Simulator identification and scenario configuration.
Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. The Test Item data will be processed and analyzed to verify navigation performance. See 2.2.2 for details of time testing.

2.2.6. Multipath Characterization

2.2.6.1. Test Objective

The purpose of this test is to characterize the accuracy of the GPS receiver's pseudo-range measurements while subjected to multipath signals, and to ascertain the impact of any measurement errors on the GPS solution output by the navigation processor. The GPS receiver will be subjected to both In-Chip and Out-Of-Chip conditions. In-Chip and Out-Of-Chip conditions refer to the offset between the delayed signal and the direct signal in terms of the fundamental clocking period (one chip) of the code. An In-Chip delay is one in which the offset is one chip or less (within one chip) and an Out-Of-Chip delay is one in which the offset is greater than one chip.

2.2.6.2. Special Test equipment.

A GPS simulator is required for this test.

2.2.6.3. Test Methods.

A. Simulator Configuration – The simulator will initially be configured to provide a nominal constellation of four satellites. The first 30 minutes of the test employs a static position scenario with good GDOP. The second 30 minutes of the test involves running one circuit of a dynamic scenario. During this one-hour data collection period, one selected satellite shall have a second, delayed signal (multipath) added to the simulated satellite signals. The multipath shall be switched from In-Chip to Out-Of-Chip every five minutes. Because the boundary between In-Chip and Out-Of-Chip is truly 1.5 chips, this testing should be conducted at a 0.5 chip offset and at a 1.5 chip offset. For additional background information about simulator configuration and operation, see Annex A.

B. Test Execution - A pseudo-range offset between the direct and delayed path signals of an SV in the satellite constellation shall be simulated. The Test Item shall be tracking 4 SVs in State 5 at the start of the test.

2.2.6.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Simulator identification and scenario configuration.
Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. Pseudo-range measurements shall be evaluated with due consideration of anomalies resulting from ionospheric estimations, position errors and relative channel delays. C/No and FOM data will be evaluated to determine if code tracking errors were due to multipath. Proper acquisition and tracking of SVs during the test shall also be evaluated. Statistics shall be calculated of the pseudo-range measurement errors during static and dynamic conditions, as a function of GDOP and during both in-chip and out-of-chip multipath conditions. See 2.2.2 for details of time testing.

2.2.7. GR Jamming.

{See GPS Receiver CTP Addendum (Distribution C)}

2.2.7.1. Test Objective.

The test objective is to verify that the Test Item maintains full navigation accuracy in a jamming environment. The jamming types suggested to be employed are:

A. Continuous wave
B. Swept continuous wave
C. Narrow band noise
D. Wide band noise
E. Pulsed

2.2.7.2. Special Test Equipment.

A GPS simulator capable of creating the required jamming signals or a separate jammer capable of creating the required jamming signals and being connected with a GPS simulator are required.

2.2.7.3. Test Methods.

A. Simulator Configuration – The simulator will initially be configured to provide a nominal constellation. Both static and dynamic conditions will be simulated. The specified jamming signal power level will be injected into the radio frequency (RF) input to the Test Item. For additional background information about simulator configuration and operation, see Annex A.
B. Reserved.

2.2.7.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Simulator identification and scenario configuration.
Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.
Jammer settings and times.

Reserved.

2.2.8. Long Duration Stability.

2.2.8.1. Test Objective.

The test objective is to ensure that the Test Item continues to function properly while operating continuously for an extended period of time.

2.2.8.2. Special Test Equipment.

A GPS antenna is required for this test.

2.2.8.3. Test Methods.

The Test Item will be initialized in a static mode with live SV signals. A crypto key fill adequate for the duration of the test will be loaded, if possible. The Test Item will be allowed to navigate continuously for a period appropriate for the intended application. The test should be scheduled to include a midnight Saturday/Sunday to ensure that an almanac and ephemeris transition is included.

2.2.8.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. Navigation solution and time data will be recorded on the RS-232, RS-422, and/or MIL-STD 1553B ports. Data will be analyzed to detect both short term “spikes” and long term drift of the navigation solution and time data. See 2.2.2 for details of time testing.

3. VAN

For systems intended to be used in a ground vehicle application, it is recommended that the installation in the van be representative of the ultimate application, including signal levels, vibration, temperature, etc. The Test Director should ensure that test methods employed in the laboratory are replicated as closely as possible in the field, to ensure that any observed changes in performance are not induced by the procedures. A suitable truth source, such as a surveyed course or a Time-Space-Positioning-Information (TSPI) system is needed to evaluate van tests. Table 2 summarizes the GR van tests, identifies the test objectives, the tests, and the CTP test description paragraph associated with each test. These tests are separated into Functional and Performance test objectives:

Table 2. GR Van Tests

Test Objective	Responsible Test	CTP Test Paragraph
Functional:		
Demonstrate acceptable:		
Van GPS Navigation Operation	Van GR Static Navigation and Time	3.1.1.
Performance:		
Evaluate:		
Navigation Accuracy	Van GR Navigation Solution and Time	3.2.1.
Acquisition Time	Acquisition Time Performance	3.2.2.
Figure of Merit (FOM)	Van FOM	3.2.3.
Signal Reacquisition	Van Signal Reacquisition	3.2.4.
RF Interference (RFI)/Jamming	Van GR Jamming	3.2.5.

3.1. Van Functional.

3.1.1. Van GR Static Navigation Solution and Time.

3.1.1.1. Test Objectives.

The test objectives are to verify that the Test Item is functioning properly as installed in the van and to determine that correct PVT is being generated, displayed, and recorded.

3.1.1.2. Special Test Equipment.

A GPS antenna is required for this test.

3.1.1.3. Test Methods.
The Test Item will be turned on, initialized, and switched to the navigation mode with the van static over a surveyed benchmark. The basic navigation configuration will be tested as well as any special modes that use additional information denoting that the host vehicle is stationary. The navigation data will be recorded from the RS-232, RS-422, and/or MIL-STD 1553B ports. The duration of the test will be at least 15 minutes for each navigation configuration/mode tested.

3.1.1.4. Data Collection and Analysis Methods.
As a minimum, test relevant data will be collected and recorded as follows:

Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. The Test Item data will be processed and analyzed to verify navigation solution and time accuracy.

3.2. Van Performance.

3.2.1. Van GR Navigation Solution and Time.

3.2.1.1. Test Objective.
The test objective is to evaluate Test Item performance under low dynamics.

3.2.1.2. Special Test Equipment.
None required.

3.2.1.3. Test Methods.
The Test Item will be turned on, initialized, and switched to navigation mode with the van static over a surveyed benchmark. The Test Item data will be recorded from both the MIL-STD 1553B port and the RS-422 instrumentation port (IP). After all systems are ready, the van will proceed around the dynamic ground course, return to the starting point, and park over the surveyed benchmark.

3.2.1.4. Data Collection and Analysis Methods.
As a minimum, test relevant data will be collected and recorded as follows:

Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.

Test Item internal accuracy estimators (FOM, EHE, etc.).

Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. For all test configurations, the accuracy of the PVT solution will be determined. Particular emphasis will be placed on analyzing Test Item operation in turns, during constellation changes, and during maneuvers.

3.2.2. Acquisition Time Performance.

As explained in Section 2.2, various acquisition programs and manufacturers have defined REAC, TTFF, etc., differently, so that it is now impossible to create a generic test using these terms. This test defines, at the broadest level, acquisition time performance testing, and should be used as a guide to develop one or more tests specific to the Test Item.

3.2.2.1. Test Objective.

The test objective is to verify that the Test Item provides navigation data within specified time requirements, given specified initial conditions and uncertainties.

3.2.2.2. Special Test Equipment.

None required.

3.2.2.3. Test Methods.

The Test Item will be configured in accordance with its specification. If critical memory is to be erased, the manufacturers recommended methods must be used to avoid unintentionally affecting other areas of the set. After the receiver has indicated achieving a successful signal reacquisition or navigation solution, it will be allowed to navigate for about 10 minutes to allow the collection of sufficient data for evaluation.

3.2.2.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Test equipment identification and calibration dates.

Test Item identification.

Test Item navigation solution and time output at 1 Hz minimum.

Test Item health status and state or tracking codes.

Test Item internal accuracy estimators (FOM, EHE, etc.).

Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. The Test Item data will be processed and analyzed to verify navigation accuracy. The data will be examined to verify that the Test Item has successfully met its specification performance requirements.

3.2.3. Van FOM.

3.2.3.1. Test Objective.

The test objective is to verify that the Test Item FOM calculation reflects the true position accuracy of the system and that the Test Item uses appropriate SV selection strategies.

3.2.3.2. Special Test Equipment.

None required.

3.2.3.3. Test Methods.

This test shall be accomplished by analyzing data collected during other dedicated tests.

3.2.3.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. The Test Item data will be processed and analyzed to verify navigation accuracy. The navigation error and FOM will be analyzed to evaluate if FOM reflects the true navigation error during all phases of van testing, in particular when jamming occurs or GPS tracking is degraded. The analysis shall verify that the FOM reflects the effects of SV geometry when GDOP is very large, when there are fewer than four satellites, when user range accuracy is set high, and/or when there is jamming. A correlation between the navigation error and FOM will be reported.

3.2.4. Van Signal Reacquisition.

3.2.4.1. Test Objective.

The test objective is to verify that the Test Item can reacquire satellites and reestablish the channel tracking states within a specified time following signal loss due to events such as blockage, jamming, and dynamics.

3.2.4.2. Special Test Equipment.

One or more GPS jammers are required for this test.

3.2.4.3. Test Methods.

This test may be conducted in conjunction with jamming tests in paragraph 3.2.5. The Test Item will be initialized and commanded to the navigation mode and allowed to acquire and track four SVs on P(Y)-code with code and carrier lock tracking. The van will traverse the ground course. After a minimum of 5 minutes of operation, jamming sufficient to cause total loss of lock (the jamming signal may be introduced with a signal generator on board the van) shall be simultaneously applied to both frequencies for periods of 30, 60, and 120 seconds, consecutively. Following each jamming period, the Test Item will be allowed to recover four SVs on P(Y)-code with code and carrier lock tracking.

3.2.4.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.
Jammer settings and times

Data will be reported in the measurement units of the requirements document. The Test Item data will be processed and analyzed to verify navigation accuracy. The data will be examined to verify that the Test Item recovered the lost SVs and the Test Item has transitioned to normal navigation. The time to reacquire for each test case will be obtained and the statistics will be calculated to determine if the Test Item met specification requirements.

3.2.5. Van GR Jamming.

{See GPS Receiver CTP Addendum (Distribution C)}

3.2.5.1. Test Objective.

The test objective is to evaluate the Test Item jamming susceptibility in a ground vehicle dynamic environment. The typical jamming types are:

A. Continuous wave
B. Swept continuous wave
C. Narrow band noise
D. Wide band noise
E. Pulsed

3.2.5.2. Special Test Equipment.

One or more GPS jammers are required for this test.

3.2.5.3. Test Methods.

Reserved.

3.2.5.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Test equipment identification and calibration dates.

Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.
Jammer settings and times.

Reserved.

4. FLIGHT

A suitable truth source, such as a Time-Space-Positioning-Information (TSPI) system or a tracking system, is needed to evaluate flight tests. In addition, the Test Manager must plan for the flight phase with care. If testing is to be done on multiple aircraft types, the test package should not be changed to accommodate installation issues, in order to ensure compatibility of test results. If the installation is to be in an aircraft that is representative of the ultimate application, its installation should replicate that installation as much as possible. However, a test installation also must accommodate a data recording capability not included in an operational installation. In all cases, advance concern must be given to mounting, power availability, antenna placement, wiring, and maintenance access, especially in more compact aircraft such as the "fighter". The flight profiles used for all flight tests on the various aircraft must be designed with care to ensure that the Test Item is stressed to reveal performance under conditions appropriate to the test objectives. Table 3 identifies GR flight tests, identifies the test objectives, test, and CTP test description paragraph associated with each test. These tests are separated into Functional and Performance objectives:

Table 3. GR Flight Tests

Test Objective	Responsible Test	CTP Paragraph
Functional:		
Demonstrate acceptable:		
Flight GPS Only Navigation	Flight GR Static Navigation	4.1.1
Performance:		
Evaluate:		
Cargo Aircraft Flight		
Navigation Accuracy	Cargo Aircraft GR Navigation	4.2.1
Acquisition Time	Acquisition Time Performance	4.2.2
Figure of Merit (FOM)	Cargo Aircraft FOM	4.2.3
Signal Reacquisition	Cargo Aircraft Signal Reacquisition	4.2.4
RF Interference (RFI)/Jamming	Cargo Aircraft GR Jamming	4.2.5
Fighter Navigation Accuracy	Fighter GR Navigation	4.2.6
Helicopter Navigation Accuracy	Helicopter GR Navigation	4.2.7

4.1. Flight Functional

4.1.1. Flight GR Static Navigation.

4.1.1.1. Test Objectives.

The test objectives are to verify that the Test Item is functioning properly as installed in the aircraft and to determine that the Test Item navigation solution is being generated, displayed, and recorded.

4.1.1.2. Special Test Equipment.

If this test is being conducted on a fighter or helicopter, the Test Manager must consider the availability of mounting points, power, and interface cabling at the location of the Test Item and ancillary test equipment.

4.1.1.3. Test Methods.

The Test Item will be turned on, initialized, and switched to the navigation mode with the aircraft parked over a surveyed benchmark. The basic navigation configuration will be tested as well as special navigation modes that use additional information that the host vehicle is stationary. The duration of the test will be at least 15 minutes for each navigation configuration/mode tested.

4.1.1.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

- Test equipment identification and calibration dates.
- Test Item identification.
- Test Item navigation solution and time output at 1 Hz minimum.
- Test Item health status and state or tracking codes.
- Test Item internal accuracy estimators (FOM, EHE, etc.).
- Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. The data will be reviewed to determine that the Test Item is functioning properly. The Test Item navigation solution will be compared with the static surveyed benchmark coordinates to verify the system is operating properly.

4.2. Flight Performance

4.2.1. Cargo Aircraft GR Navigation Solution and Time.

4.2.1.1. Test Objective.

The test objective is to evaluate the Test Item performance during medium/high dynamics.

4.2.1.2. Special Test Equipment.
None required.

4.2.1.3. Test Methods.
The Test Item will be turned on, initialized, and switched to the navigation mode with the aircraft static over a surveyed benchmark, and allowed to achieve a stable navigation solution. The GPS receiver data will be recorded on both the MIL-STD 1553B and the RS-422 ports. After all systems are ready, the aircraft will fly the selected flight profiles and return to the starting point and park over the surveyed benchmark.

4.2.1.4. Data Collection and Analysis Methods.
As a minimum, test relevant data will be collected and recorded as follows:

Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. The Test Item position and velocity data from both the MIL-STD-1553B and IP ports will be compared with the reference data. For all test configurations, the navigation accuracy of the navigation solution will be determined. Particular emphasis will be placed on analyzing Test Item operation in turns, during constellation changes, and during maneuvers. Anomalous behavior will be noted.

4.2.2. Acquisition Time Performance.
As explained in Section 2.2, the parameters of REAC, TTFF, etc., have been defined differently by various acquisition programs and manufacturers, so that it is now impossible to create a generic test using these terms. The following test defines, at the broadest level, this type of testing, and should be used as a guide to develop one or more tests specific to the Test Item.

4.2.2.1. Test Objective.
The test objective is to verify that the Test Item provides navigation data within specified time requirements, given specified initial conditions and uncertainties.

4.2.2.2. Special Test Equipment.
None required.

4.2.2.3. Test Methods.
The Test Item will be configured in accordance with its specification. If critical memory is to be erased, the manufacturers recommended methods must be used to avoid unintentionally affecting other areas of the set. After the receiver has indicated

achieving a successful signal reacquisition or navigation solution, it will be allowed to navigate for about 10 minutes to allow the collection of sufficient data for evaluation.

4.2.2.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. The Test Item data will be processed and analyzed to verify navigation accuracy. The data will be examined to verify that the Test Item has successfully met its specification performance requirements.

4.2.3. Cargo Aircraft FOM.

4.2.3.1. Test Objective.

The test objective is to verify that the Test Item FOM calculation reflects the true position accuracy of the system and that the Test Item uses appropriate SV selection strategies to maintain the optimal SV tracking configuration.

4.2.3.2. Special Test Equipment.

None required.

4.2.3.3. Test Methods.

The Test Item will be initialized and then commanded into the standalone navigation mode. Data will be recorded during all other cargo aircraft tests.

4.2.3.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.)
Test Item MIL-STD 1553B and IP data

Data will be reported in the measurement units of the requirements document. The Test Item data will be processed and analyzed to verify navigation accuracy. The navigation error and FOM will be analyzed to evaluate if FOM reflects the true navigation error, in particular when jamming occurs or GPS tracking is degraded. The analysis will verify that the FOM reflects the effects of SV geometry when GDOP is very large, when there are fewer than four satellites, when user range accuracy is set high, and/or when there is jamming. A correlation between the navigation error and FOM will be reported.

4.2.4. Cargo Aircraft Signal Reacquisition.

4.2.4.1. Test Objective.

The test objective is to verify that the Test Item can reacquire satellites and reestablish the channel tracking states within a specified time following signal loss due to events such as blockage, jamming, and aircraft dynamics.

4.2.4.2. Special Test Equipment.

One or more GPS jammers are required for this test.

4.2.4.3. Test Methods.

This test may be conducted in conjunction with jamming tests, below. The Test Item will be initialized and commanded to the navigation mode and allowed to acquire and track 4 SVs on P(Y)-code with code and carrier lock tracking. The aircraft will begin the flight mission. After a minimum of 5 minutes of operation, jamming sufficient to cause loss of lock (the jamming signal may be introduced by a signal generator on board the aircraft) will be simultaneously applied to both frequencies for periods of 30, 60, and 120 seconds, consecutively. Following each jamming period, the Test Item will be allowed to recover 4 SVs on P(Y)-code with code and carrier lock tracking.

4.2.4.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

- Test equipment identification and calibration dates.
- Test Item identification.
- Test Item navigation solution and time output at 1 Hz minimum.
- Test Item health status and state or tracking codes.
- Test Item internal accuracy estimators (FOM, EHE, etc.).
- Test Item MIL-STD 1553B and IP data.
- Jammer settings and times.

Data will be reported in the measurement units of the requirements document. The Test Item data will be processed and analyzed to verify navigation accuracy. The data will be examined to verify that the Test Item recovered the lost SVs after the jamming was removed and transitioned to normal navigation. The time to reacquire for each test case will be obtained and the statistics developed described to determine if the Test Item met specification requirements.

4.2.5. Cargo Aircraft GR Jamming.

{See GPS Receiver CTP Addendum (Distribution C)}

4.2.5.1. Test Objective.

The test objective is to evaluate the Test Item jamming susceptibility in an aircraft dynamic environment.

4.2.5.2. Special Test Equipment.

One or more GPS jammers are required for this test.

4.2.5.3. Test Methods.

Reserved.

4.2.5.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.
Jammer settings and times.

Reserved.

4.2.6. Fighter GR Navigation.

4.2.6.1. Test Objective.

The test objective is to verify the Test Item's navigation performance in a high dynamic fighter environment.

4.2.6.2. Special Test Equipment.

The Test Manager must consider the availability of mounting points, power, and interface cabling at the location of the Test Item and ancillary test equipment.

4.2.6.3. Test Methods.

The Test Item will be turned on, initialized, and switched to the navigation mode with the aircraft static over a surveyed benchmark. The navigation data will be recorded from both the MIL-STD 1553B and the RS-422 ports. After all systems are ready, the aircraft will fly the selected flight profiles and return to the starting point and park over the surveyed benchmark.

4.2.6.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. For all test configurations, the accuracy of the navigation solution will be determined. Particular emphasis will be placed on analyzing test item operation in turns, during constellation changes, and during maneuvers.

4.2.7. Helicopter GR Navigation.

4.2.7.1. Test Objective.

The test objective is to verify the Test Item's navigation performance in a high dynamic helicopter environment.

4.2.7.2. Special Test Equipment.

The Test Manager must consider the availability of mounting points, power, and interface cabling at the location of the Test Item and ancillary test equipment.

4.2.7.3. Test Methods.

GPS antenna location should be considered to minimize rotor blade modulation effects. The Test Item will be turned on, initialized, and switched to the navigation mode with the aircraft static over a surveyed benchmark. The navigation data will be recorded from both the MIL-STD 1553B and the RS-422 ports. After all systems are ready, the aircraft will fly the selected flight profiles and return to the starting point and park over the surveyed benchmark.

4.2.7.4. Data Collection and Analysis Methods.

As a minimum, test relevant data will be collected and recorded as follows:

Test equipment identification and calibration dates.
Test Item identification.
Test Item navigation solution and time output at 1 Hz minimum.
Test Item health status and state or tracking codes.
Test Item internal accuracy estimators (FOM, EHE, etc.).
Test Item MIL-STD 1553B and IP data.

Data will be reported in the measurement units of the requirements document. For all test configurations, the accuracy of the navigation solution will be determined. Particular emphasis will be placed on analyzing test item operation in turns, during constellation changes, and during maneuvers. Anomalous behavior will be noted.

ANNEX A TO GLOBAL POSITIONING SYSTEM

CORE TEST PLAN

Test Item Accuracy Determination Using a GPS Simulator

ACRONYMS

CTP	Core Test Plan
DC	Direct Current
DOP	Dilution Of Position
ECEF	Earth Centered Earth Fixed
GPS	Global Positioning System
LENU	Local East North Up
SA/A-S	Selective Availability/Anti-Spoof
SSCWG	Satellite Simulator Control Working Group
PC	Personal Computer
PVT	Position, Velocity, and Time
UTC	Universal Time Constant
WGS	World Geodetic System
Vdc	Volts direct current

Test Item Accuracy Determination Using a GPS Simulator

This Annex results from input from the GPS Satellite Simulator Control Working Group (SSCWG) and supplements the GPS Receiver Core Test Plan (CTP). It details the items to be considered when conducting simulator testing of a GPS receiver. Many variables can affect the accuracy performance of a GPS receiver while it's navigating using the signals provided by a GPS simulator. To get consistent, repeatable test results from different test agencies, and even within a single agency, the test community must establish common simulator set-up and test procedures. Common simulation variables such as start position, start time, dynamic profile definition, ephemeris and almanac parameters, satellite clock terms, and atmospheric delay (ionosphere and troposphere) modeling can all impact the performance of the GPS system under test.

1. SCOPE

1.1. Purpose.

The purpose of this Annex is to establish common procedures and GPS simulator set-up parameters that can be used to determine the accuracy of a GPS receiver. The procedures herein are for guidance only, and are only applicable for accuracy testing. These standard GPS simulator set-up configurations and test methods should lead to repeatable test results.

1.2. Limitations.

The procedures and methods described below apply to testing a wide variety of GPS receiver systems using a typical GPS simulator, but may not apply to unique integrations and/or applications. The procedures are used as guidelines to assist in establishing consistency of testing. It should also be noted that the systems under test are not actually in motion. Thus, the simulated GPS signal environment is the only aspect being considered.

Since several GPS simulator manufacturers exist and each may have a different user interface, the specific procedures for the configuration of each unique simulator will not be addressed. Rather, general set-up guidelines that could be applied to each unique system are discussed.

1.3. Disclaimer.

The use of trade names in this Annex does not constitute an official endorsement or approval of the use of such commercial hardware or software. This Annex may not be cited for purposes of advertisement.

2. FACILITIES AND INSTRUMENTATION

2.1. Facilities.

The facility must contain a laboratory test area that has sufficient security measures to house the GPS simulator as well as military GPS receivers. The facility should also provide conditioned external power sources and back-up power to reduce test interruption in the event of short-term power outages.

2.2. Instrumentation.

As shown in Figure 1, the basic test configuration consists of a GPS Simulator, the GPS receiver under test, a data collection system (normally a PC/buffer box) and data analysis tools.

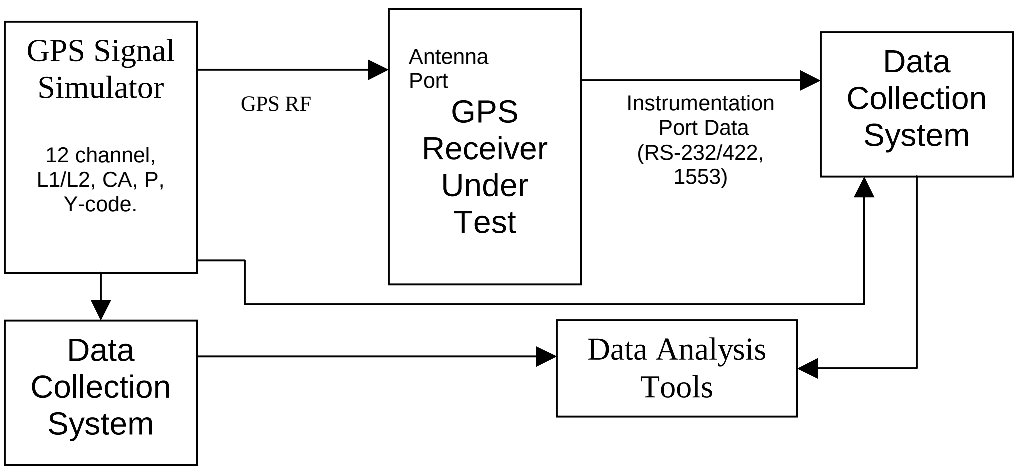


Figure 1. Basic Test Configuration

2.2.1. GPS Simulator.

The GPS Simulator is used to provide the required GPS signals to the GPS receiver under test. Most modern GPS simulators are capable of simulating the signals of up to 12 complete GPS satellites at one time. 12-channel coverage is not required, but recommended to allow "all-in-view" simulations. Selective Availability and Anti-spoofing (SA/A-S) capabilities are required for testing military GPS receivers and this option is available for many GPS simulators. The truth data (typically ECEF position, velocity, and time) is normally recorded from the simulator to allow comparison with the navigation solution of the GPS receiver under test. This data may be recorded internally within the simulator or externally using a PC, depending on the GPS simulator's architecture.

2.2.2. GPS Simulator-to-GPS Receiver interface.

The simulated GPS signal is injected into the antenna port of the GPS receiver under test. It is important to establish the proper input signal level at the antenna port of the GPS receiver. There are a variety of antenna/pre-amplifier configurations used on GPS systems and being familiar with the configuration before testing is required. A non-amplified antenna system will normally accept input GPS signals at nominal, live levels directly at the antenna port. On the other hand, if an amplified antenna system (which requires a DC voltage provided to the antenna) is incorporated, a simple “matching” network may be required. This will simulate the remote antennas electrical characteristics and allow the GPS receiver to accept the simulated GPS signals. Figure 2 shows the basic network required to inject the simulated GPS signal into a GPS receiver that normally uses an external amplified antenna.

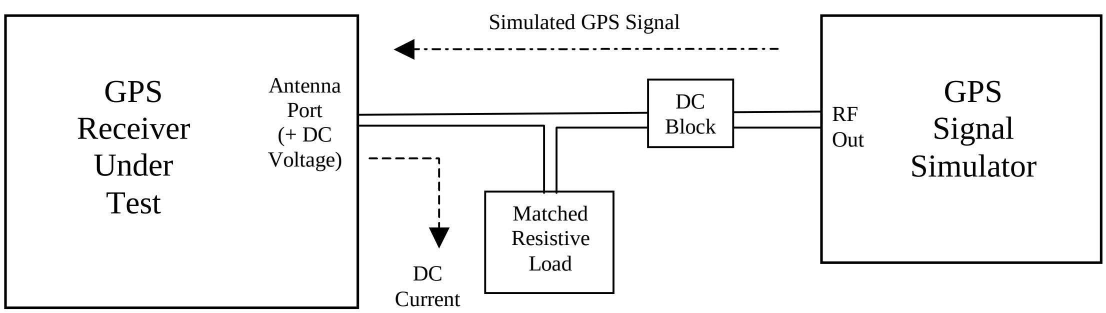


Figure 2. GPS Receiver antenna matching set-up.

As shown in Figure 2, the dc current that is normally consumed by the remote antenna is presented to the resistive load to simulate the antenna. Care must be taken to properly match the receiver’s antenna port dc output voltage and the resistive load to establish the proper current flow from the antenna port. If a significant mismatch occurs the receiver may indicate an external antenna fault and will not track properly. Simple measurement of the voltage (normally from 5-15 Vdc) and current with an external antenna connected can preclude mismatch problems.

Once the proper matching is accomplished, the gain of the amplified antenna must be known to achieve nominal signal levels at the GPS receiver’s antenna port. Compensation of the antenna gain is achieved by increasing the output signal level of the simulator to compensate for the lack of amplification. Additionally, any cable losses due to the length of coaxial cable between the GPS simulator and receiver under test should be characterized and proper compensation applied.

2.2.3. Instrumentation Port

Most GPS receivers have an instrumentation port that provides the navigation solution (position, velocity, and time (PVT)) over an RS-232/422 serial interface. Other interfaces that may be present are MIL-STD-1553 or ARINC 429. The PVT data from the GPS receiver is recorded and compared (using data analysis tools) to the PVT data generated from the GPS simulator (truth) to determine the accuracy of the GPS receiver. The method of recording this data is receiver specific and may contain additional information, based on test requirements.

3. <u>TEST CONDITIONS</u>

3.1. GPS Simulator set-up parameters.

There are many simulator set-up considerations that should be addressed prior to executing this accuracy test. These are:

- Simulation Start Date and Time.
- Simulation Position.
- Ephemeris and Almanac.
- Satellite Clock Terms.
- GPS – UTC Time Translation Parameters.
- Atmospheric Delay Modeling.

In most cases, the GPS simulator will insert default values into these parameters. Default values are not likely to corrupt a unique test conducted with a particular simulator, but if the test is repeated using a different simulator, the default values used may be different. This would likely affect the resultant accuracy of the GPS receiver under test, thus yielding different results. It is important to consider and verify that these parameters are held constant among tests to get the most repeatable and comparable results.

3.1.1. Start Date/Time and Position

The scenario start date and time and start position (including elevation) are typically user entered and can significantly affect the performance of the GPS system under test due to varying satellite coverage. In many cases, the simulation start times and position are chosen to yield specific coverage and visibility of certain satellites especially if the intention is to characterize the receiver's ability to perform in less than optimum conditions. The simulation start time is normally referenced to a GPS week for which the simulation will apply and must match the applicability date of the ephemeris data. The position is entered similarly and can normally be entered in a variety of formats including Lat/Long or earth-centered earth-fixed (ECEF). Using a standard simulation start time and position (along with ephemeris data described below) will ensure that the GPS receiver under test is exposed to common satellite visibility conditions.

3.1.2. Ephemeris and Almanac Parameters.

The ephemeris parameters describe each satellite's orbit and include correction terms to account for perturbations of the orbit. The GPS simulator will produce ephemeris data as part of the navigation message (sub frames 2 & 3) transmitted for each satellite. Since these data predict current satellite position, it is important that this information is consistent between tests. Most GPS simulators will generate an applicable set of ephemeris parameters based on a default or “canned” ephemeris starting point. These values will be propagated to the user indicated date and time of the scenario. Since not all GPS simulator vendors use the same canned ephemeris values, large differences may exist in the satellite coverage and availability for a given date/time. Changing certain parameters in the ephemeris results in different satellite visibility and coverage, which will affect the Dilution of Precision (DOP) at any given time during the scenario. The DOP is basically the geometric contribution to position error for a given location and time. An example of a set of ephemeris parameters for one satellite is shown below:

**** Week 0893 ephemeris for SV- 5 ************		
ID:	5	
Eccentricity:	1.952426275E-03	e
Time of Applicability(s):	3.599840000E+05	TOE
Orbital Inclination(rad):	9.372728454E-01	I_0
Rate of Right Ascen(r/s):	-8.286059664E-09	OMEGA_DOT
SQRT(A) (m^1/2):	5.153781679E+03	SQRT_A
Right Ascen at TOA(rad):	1.942633791E+00	OMEGA_0
Argument of Perigee(rad):	1.954183053E-01	OMEGA
Mean Anom(rad):	-2.795994470E+00	M_0
mean motion diff(r/s):	5.000565576E-09	DELTA_N
Rate of inclin (r/s):	2.442958970E-10	I_DOT
lat cosine ampl (r):	-9.313225746E-09	CUC
Lat sine ampl (r):	8.447095752E-06	CUS
radius cos ampl (m):	2.044375000E+02	CRC
radius sin ampl (m):	4.643750000E+01	CRS
inclin cos ampl(r):	-3.725290298E-09	CIC
inclin sin ampl(r):	-9.313225746E-09	CIS
week:	0893	
t_gd:	-4.190951586E-09	T_GD
t_oc:	3.599840000E+05	T_OC
Af0(s):	2.359435894E-04	af0
Af1(s/s):	1.932676241E-12	af1
Af2(s/s/s):	0.000000000E+00	af2

It is recommended that a characterized, common set of ephemeris parameters be input into the simulator prior to the beginning of the test to minimize the potential adverse effects. Current and historic almanacs are available for download at http://www.gpstestcoe.com.

The Almanac parameters included in the navigation message (subframe 4) are fewer and less accurate than the ephemeris parameters. When transmitted from the satellite, this information is primarily used for satellite selection and aids the receiver in initial acquisition. An example of a set of almanac parameters for one satellite is shown below:

**** Week 0893 almanac for PRN-01 ***********	
ID:	01
Health: 000	
Eccentricity:	4.933834076E-003
Time of Applicability(s):	61440.0000
Orbital Inclination(rad):	9.615267216E-001
Rate of Right Ascen(r/s):	-8.046049436E-009
SQRT(A) (m^1/2):	5153.618652
Right Ascen at TOA(rad):	2.192091128E+000
Argument of Perigee(rad):	-1.729656591E+000
Mean Anom(rad):	-8.394949546E-003
Af0(s):	1.430511475E-004
Af1(s/s):	0.000000000E+000
week:	0893

Typically, GPS simulator systems allow for operator entry of specific almanac or ephemeris data to be used by the scenario. Manipulating the almanac and ephemeris data conditions can induce less than optimal satellite coverage. Therefore, it is important to use a representative set of initial ephemeris data. Often times, these data can be downloaded from a GPS receiver tracking live satellites or taken from various GPS information sites such as http://www.gpstestcoe.com. It is important to use a consistent set of ephemeris and/or almanac parameters to ensure repeatable test conditions.

3.1.3. Satellite Clock Error Terms.

The GPS simulator will produce satellite clock correction values as part of the navigation message (subframe 1) transmitted for each satellite. In the live environment these values are determined by the Master Control Station and transmitted to the satellite for re-broadcast in the navigation message. These correction parameters are as follows:

- Clock bias (af0)
- Clock drift (af1)
- Frequency drift (af2)
- Clock data ref time (toc)
- Current time epoch (t)
- Correction due to relativistic effects (tr)

Many GPS simulators offer the ability to modify these terms via a separate menu. The primary concern is that consistency is maintained when generating scenarios with respect to the clock correction term values. During the scenario definition these values should be checked for consistency.

3.1.4. GPS - UTC Time Translation Parameters

Since GPS time is based on an atomic clock that is continuously transmitted from the satellite without the leap seconds associated with UTC time, correction parameters must be provided to allow the GPS receiver to convert GPS time to UTC time. These parameters are contained in the navigation message (subframe 4) produced by the simulator and are normally user-entered at a menu. The GPS-UTC translation parameters are as follows:

- Constant Term in Polynomial (Ao)
- First Order term in Polynomial (A1)
- Delta time due to leap seconds.
- Reference time for UTC data.
- UTC Reference week number.
- Reference Week number for future leap seconds.
- Day number.
- Delta Time due to Future Leap Seconds.

Since these parameters include such values as the number of leap seconds and when in time they will apply, it is important to ensure these parameters are consistent between GPS simulations to achieve common time reporting.

3.1.5. Atmospheric delay modeling (Ionospheric and Tropospheric).

GPS receivers may employ Ionospheric and/or Tropospheric Delay Models to correct for the effect of signal delays on the signal-in-space while it is passing through the earth's atmosphere. GPS simulators employ these same various Ionospheric and Tropospheric Delay Models to create this effect on their simulated signals. In many cases, there are a variety of models that can be selected from the simulator's control menu. Below are some common examples of these models:

Ionospheric Delay Models	Tropospheric Delay Models
- Single frequency model	- Collins Phase III
- Uniform Density Shell model	- Collins Phase II
- Klobuchar model	
-Constant Rate Model	

Since the signal delays can be significant (especially for satellites at low elevation angles), it is important to know which model(s) are used in the receiver being tested, and to know that if the model(s) selected for use in the simulator is the same, receiver performance may be enhanced. If testing is to be conducted on multiple simulators, a common choice of models should be employed.

Ionospheric delay parameters are transmitted within the navigation message (subframe 4) to be used by the receiver in the modeling process.

3.1.6. Stationary profile.

The stationary profile simulates a GPS receiver at rest. The simulated GPS constellation progresses through its normal dynamics (rising and setting satellites), while the user platform does not move.

3.1.7. Dynamic Profiles.

The operator can define the desired dynamic profile for a GPS receiver in motion. There are normally two primary methods of establishing profiles within the simulator, a built in trajectory generator and an external trajectory generator.

Built in trajectory generator: Most GPS simulators contain a resident “user motion generator” which allows the user to define the scenario based on a series of high level commands. These commands are typically based on event timing and will contain maneuvers like “*at t=10 sec, change speed to*:”, “*change heading to*:”. These built in commands eliminate the need for the operator to precisely control each maneuver, and the simulator resolves any discontinuities between maneuvers. This method has the drawback that the system “fits” the maneuvers together so it is rare to achieve the *exact* same dynamic profile when dealing with different GPS simulator system vendors. This may make it difficult to compare GPS receiver performance results when tested on different simulators. The advantage of the built in system is that the profiles are usually easy to create. The dynamic profile described in Figure 1, *Standard Yuma Proving Ground Simulated Racetrack Profile*, and Table 2, *Trajectory Profile*, of the GPS CTP is an example of this type of trajectory.

External trajectory generator: This is an option that many GPS simulators include, which allows the dynamic scenario to be provided from an external source such as recorded PVT from actual field test data or data processed elsewhere. Most simulators specify the format of this data and it can often be provided as an ASCII file updated at a 10 Hz rate. The north and east motion of these trajectory profiles are often defined by 7^{th} order polynomials in time to produce very realistic dynamics. By updating the trajectory at a 10 Hz rate and precisely defining the position (and time derivatives - velocity and acceleration) at each update, the trajectory is consistent between maneuvers. This allows very good repeatability when a common trajectory is used on different GPS simulators since the “ambiguity” between maneuvers is removed.

3.2. Scenario Definition.

To assist in establishing a common scenario profile, the parameters described in sections 3.2.1 through 3.2.4 below and the associated data files can be used. It is important that the specified profile, almanac data, UTC, and atmospheric parameters are used to help ensure consistency. The following basic scenario set-up parameters are used:

Start Time:	00:00 (UTC time)
Start Date:	2/23/97
Start Position:	N 33° 0.0’ 0.0’’, W 117° 0.0’ 0.0”, 0 m (datum altitude)
Start Heading:	0º
Start Velocity:	0

3.2.1. Vehicle Profile.

The profile combines periods of dynamics and stationary conditions. The three hour and 45 minute scenario is partitioned into static and dynamic periods as follows:

A. 0:00 - 1:15 static
B. 1:15 - 1:45 dynamic
C. 1:45 - 2:15 static
D. 2:15 - 2:45 dynamic

E. 2:45 - 3:15 static

The dynamic portions of the profile consist of a five-minute loop repeated six times during each dynamic portion of the scenario. The five-minute loop begins and ends with the vehicle stationary (approximately). The motion is defined in a Local East-North-Up (LENU) coordinate system centered at 33 degrees north latitude and 117 degrees west longitude, on the WGS-84 ellipsoid. The motion is determined by two seventh degree polynomials, one giving position in meters as a function of time in the east axis, the other in the north axis. These polynomials are defined as follows:

$$East(t) = e_0 + e_1*t + e_2*t^2 + e_3*t^3 + e_4*t^4 + e_5*t^5 + e_6*t^6 + e_7*t^7$$
$$North(t) = n_0 + n_1*t + n_2*t^2 + n_3*t^3 + n_4*t^4 + n_5*t^5 + n_6*t^6 + n_7*t^7$$

where,

$e_0 = -4.292947051050665*10^{-10}$
$e_1 = 1.839701209939923*10^{-3}$
$e_2 = -2.763153154769556*10^{-2}$
$e_3 = 9.252664448126804*10^{-2}$
$e_4 = -1.809709623386738*10^{-3}$
$e_5 = 1.194081434297117*10^{-5}$
$e_6 = -3.297237534656104*10^{-8}$
$e_7 = 3.28468111961149*10^{-11}$

$n_0 = -1.054859403517086*10^{-8}$
$n_1 = 7.133599794465932*10^{-3}$
$n_2 = -1.07121079362214*10^{-1}$
$n_3 = 3.584565790906435*10^{-1}$
$n_4 = -5.956432046984027*10^{-3}$
$n_5 = 3.571083860640097*10^{-5}$
$n_6 = -9.256309728667498*10^{-8}$
$n_7 = 8.815533063839785*10^{-11}$

For convenience in implementation on simulators, the LENU and ECEF position, velocity, acceleration and jerk have been calculated for each integral second and stored as files in both Excel format and ASCII:

trj_lenu.xls - Excel format, LENU at N33, W117, on the WGS-84 ellipsoid

trj_ecef.xls - Excel format, WGS-84 ECEF rectangular coordinates

trj_lenu.txt - Text ASCII, LENU at N33, W117, on the WGS-84 ellipsoid

trj_ecef.txt - Text ASCII, WGS-84 ECEF rectangular coordinates

Note, the end of one loop and the beginning of the next contains a slight discontinuity that could cause the receiver to break lock. To eliminate the discontinuity, the last second of the loop has been modified from the polynomials given above. The change provides a constant velocity from the end of the loop, to the end of the first second in the next loop. The Excel and text files listed above contain the necessary data values.

In using the Excel or text files to produce the trajectory for an entire dynamic interval it should be noted that the last point (point 300), becomes the first point (point 0) for the next loop. Thus point 0 for the second and subsequent loops is redundant and should not be used.

3.2.2. Almanac data.

Utilize the attached almanac (*almanac.alm*) data file to provide the GPS simulator with the appropriate almanac information. This is a broadcast almanac transmitted by one of the live satellites during the first few hours of June 15, 1997, with the week number changed to 894. If the simulator to be used accepts the input of complete ephemeris data, the associated ephemeris file *ephem3.sim* can be used.

3.2.3. UTC parameters.

Ensure that the following UTC parameters are used at the GPS Simulator.

A0(s):	0.00000000000e+00
A1(s/s):	0.00000000000e+00
DeltatLS(s):	11
tot(s):	147456
WNt(weeks):	0
WNlsf(weeks):	144
DN(days):	2
deltatlsf(s):	12

3.2.4. Atmospheric Delay Parameters (Iono and Tropo).

The single frequency ionosphere model is employed with the following parameters:

a0(s):	5.58793544769e-09
a1(s/semi-circle):	1.49011611938e-08
a2(s/semi-circle^2):	-5.96046447754e-08
a3(s/semi-circle^3):	-1.19209289551e-07
b0(s):	8.39680000000e+04
b1(s/semi-circle):	9.83040000000e+04
b2(s/semi-circle^2):	-6.55360000000e+04
b3(s/semi-circle^3):	-5.24288000000e+05

The Collins phase III (or similar) troposphere model is employed using the following parameters:

Zenith Delay:	0m
Scale Height:	10m

Note: A 10-degree satellite visibility mask is established for this scenario to minimize the effects of differing tropospheric modeling implementation.

4. TEST PROCEDURES

The following general test procedures can be used to establish a scenario, conduct the test, and review the data for a standard GPS simulation.

4.1. System Configuration.

{See GPS Receiver CTP Addendum (Distribution C)}

A. Configure the GPS simulator as described in Section 3.2 (Scenario Definition) as closely as possible to the recommended parameters. Any deviations should be noted.
B. Determine the nature of the external antenna port of the GPS receiver as described in section 2.2.2 (GPS Simulator to GPS Receiver Interface) and attach the appropriate matching load between the GPS receiver and simulator.
C. Configure the GPS receiver data collection system to record the navigation solution of the GPS receiver under test. At a minimum, collect GPS time, current position, and velocity data at a 1 Hz rate.
D. Reserved.
E. Reserved.

4.2. Test Conduct.

A. Initiate the scenario at the GPS simulator.
B. Place the GPS receiver in the Navigation (or normal tracking) mode and verify that the unit is tracking the GPS simulator signals at nominal levels.
C. Start the data collection system to record the output of the GPS receiver and the GPS simulator truth data. This should run throughout the duration of the scenario. Record the start times in a test log as well as any associated file names for future reference.
D. Allow the receiver to track satellites until it is has a complete almanac (normally about 13 minutes). During this period, confirm normal operation of both the GPS simulator and receiver.
E. Allow the GPS receiver to operate through the duration of the scenario noting any anomalous behavior of the GPS receiver or simulator.

4.3. Data Analysis.

A. At the conclusion of the scenario, harvest the simulator truth data and the GPS receiver output data from the respective data collection systems.
B. Align the two data files based on GPS time from each file.
C. Simple differencing of position, velocities, and other collected parameters will yield the errors of the associated parameters. Often commercial software such as Excel is adequate. An example of a position error plot is shown in Figure 3.

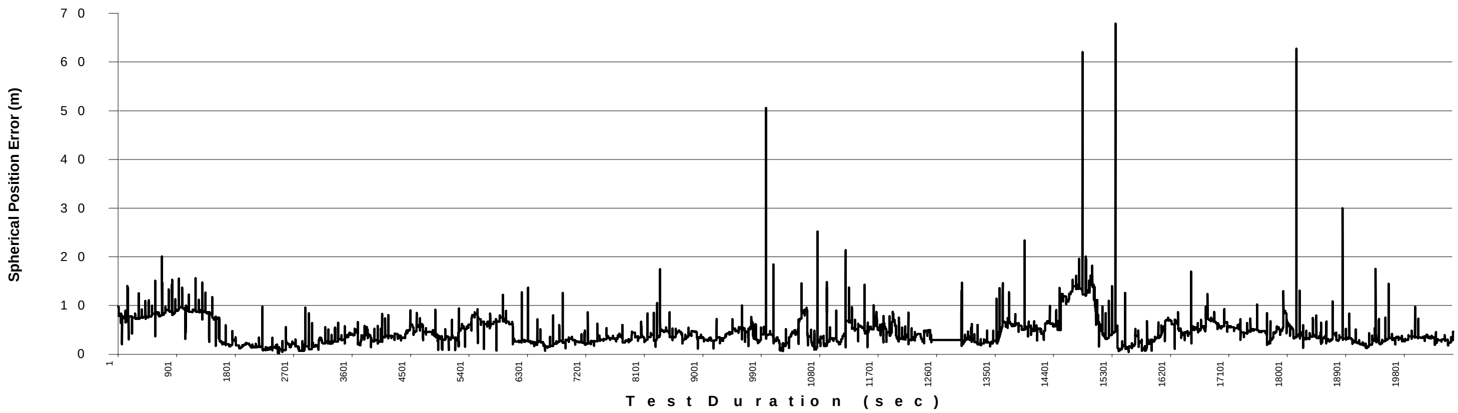


Figure 3. Example of position error plot.

D. Once the differences are determined, a representative plot can be generated. These differences can be statistically analyzed to determine specification compliance of the particular GPS receiver being tested.

E. More elaborate, automated data analysis can be utilized based on the test requirements and the exact tools to be used or developed should be considered early during test preparation.

ANNEX B TO GLOBAL POSITIONING SYSTEM

CORE TEST PLAN

Tutorial on Means, Sigmas, Confidence Intervals and Tests

Tutorial on Means, Sigmas, Confidence Intervals and Tests

Introduction.

The number of tests necessary to verify system performance has become a significant issue relating to cost and schedule. Previous methods used a confidence limit relating to a specific performance parameter, which is not applicable for all systems. Statistically, the number of tests by evaluating system performance can be estimated or quantified.

Mean and Sigma

For a test event consisting of:

j = 1 to J tests conducted, during which
i = 2 to I data points are collected per test, and
n = IJ, the total number of data points (I being the same for each of J tests, for mathematical simplicity)

Where:

μ_j and σ_j^2 = the mean and variance of the jth test
$\overline{\mu}$ = average of all the μ_j with a variance σ_μ^2
$\overline{\sigma^2}$ = simple average of the J variances σ_j^2

It can be shown (Appendix A) that:

$$\sigma_n^2 = \sigma_\mu^2 + \overline{\sigma^2} \qquad \textit{Equation 1}$$

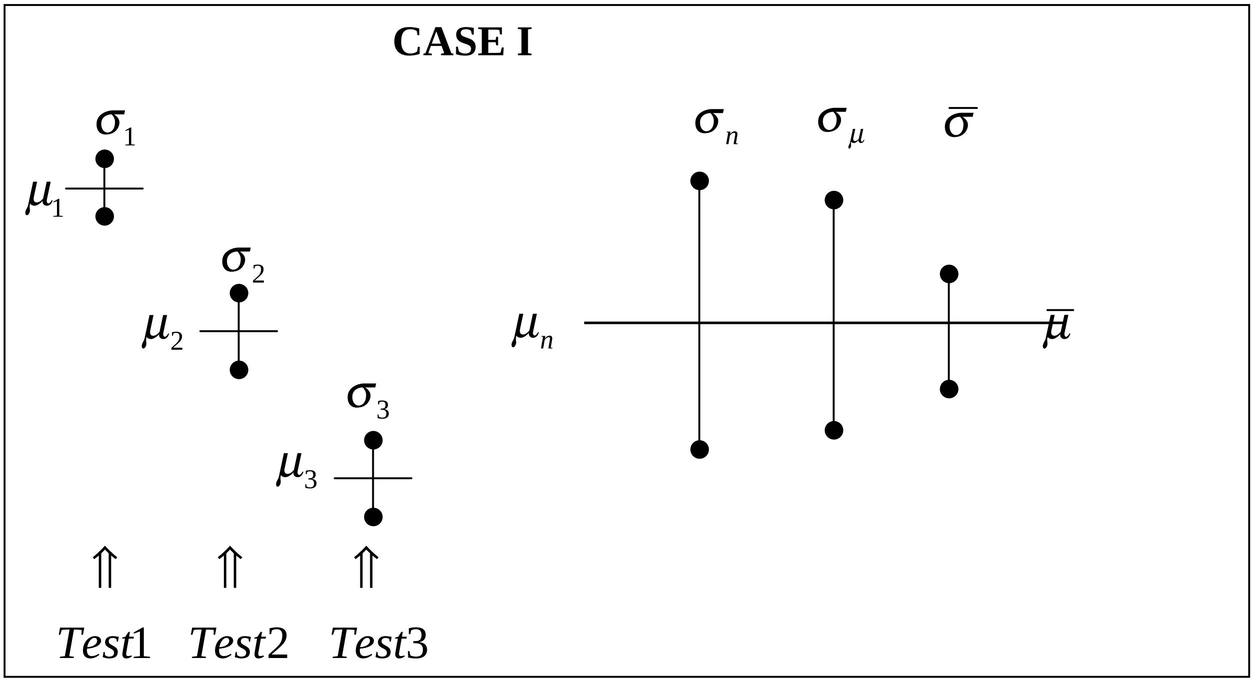
where

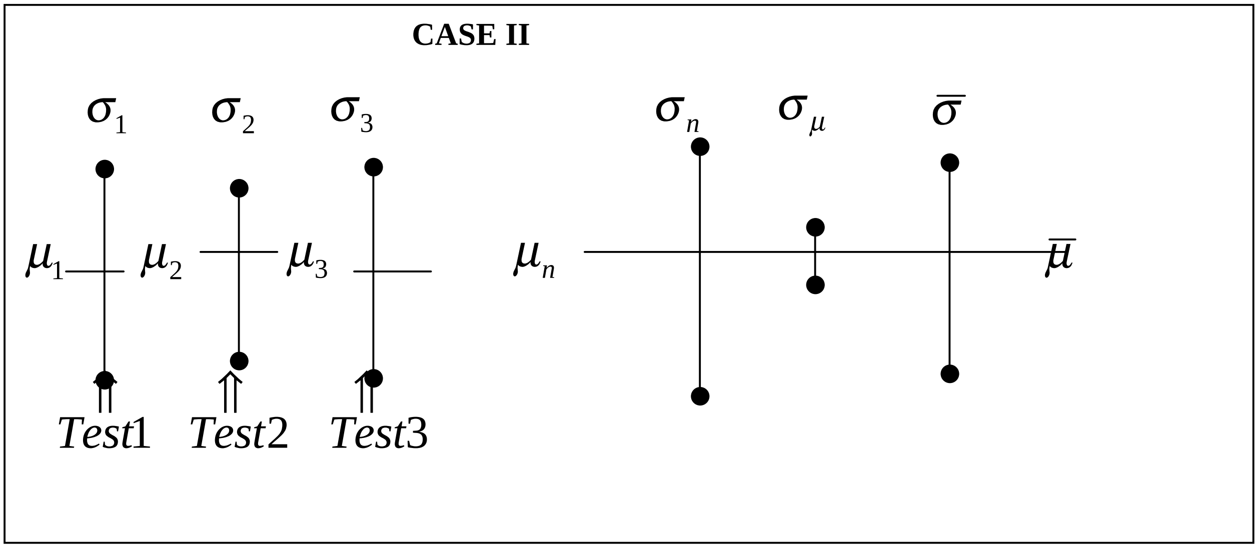
σ^2 variances associated with performance parameters
μ derived from data from a series of tests with

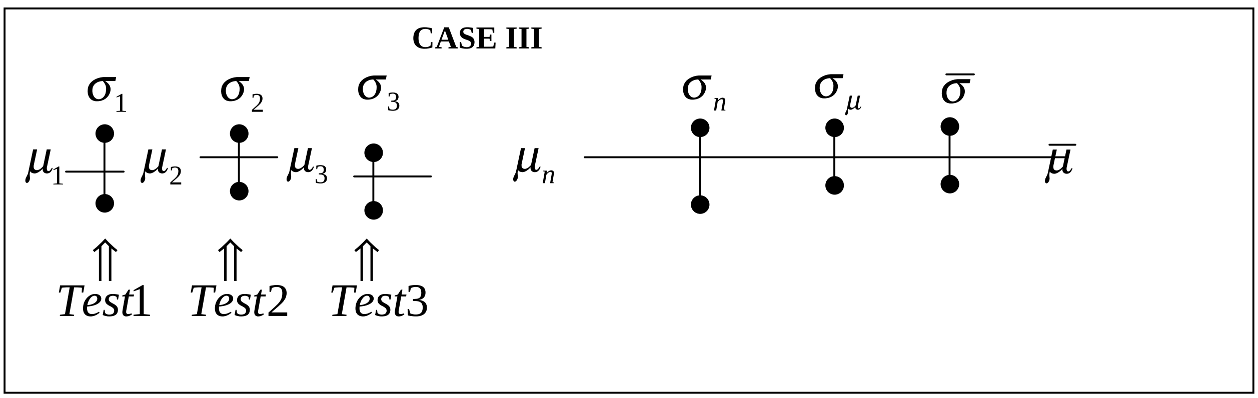
a. $i = 2$ to I data points per test
b. $j = 1$ to J tests
c. $n = IJ$ the total number of data points
(I is the same for each of J tests for mathematical simplicity)

n data points produce a single mean μ_n and variance σ_n^2
J^{th} test data produce a single mean μ_j and variance σ_j^2
$\overline{\mu}$ average of all the μ_j with a variance σ_μ^2
$\overline{\sigma^2}$ simple average of the J variances σ_j^2

The above is pictorially represented by using the glyp μ σ to denote a mean μ bounded by plus and minus sigma (square root of a variance). For notational simplicity, $\sigma_n, \sigma_\mu, \overline{\sigma}$ is used to denote the square root of $\sigma_n^2, \sigma_\mu^2, \overline{\sigma^2}$ with the following Cases developed to illustrate possible test combinations.







In Case I, three tests provided widely different results μ_j, with small variances σ_j^2 for each test, meaning that the test item was very well behaved during each test but changed from test to test: producing the characteristics of large σ_μ^2 and small $\overline{\sigma^2}$.

In Case II, three tests provided nearly identical results μ_j, with very large variances σ_j^2, meaning that the test item was noisy at all times but was telling the same story from test to test: producing the characteristics of small σ_μ^2 and large $\overline{\sigma^2}$.

In Case III, three tests provided similar results μ_j, with small variances σ_j^2, meaning that the test item was well behaved not only during each test but across the test series: producing the characteristics of equivalent σ_μ^2 and $\overline{\sigma^2}$.

From Equation 1, σ_n^2 becomes large with either large σ_μ^2 or $\overline{\sigma^2}$ and therefore by itself provides no insight into during-test or test-to-test test item behavior. Although perhaps not intuitively obvious to the most casual observer, the above is basically a restatement of the Central Limit Theorem.

Confidence Intervals.

The cases can be used to illustrate the complexity of assigning confidence levels to test item performance.

Rule: Confidence intervals can always be computed, providing that two or more samples exist. Confidence intervals are defined in terms of the data average $\overline{X}$ and the associated standard deviation S. In general form:

$$\mu = \overline{X} \pm W\sqrt{\frac{S^2}{n}} \qquad \textit{Equation 2}$$

where, as the number of samples n becomes large, $\overline{X}$ approaches the true mean μ and S^2 approaches the true variance σ^2. W is a statistic (a number) dependent both on the confidence level desired (e.g., 95%, so you can say, " I am 95% confident that μ is within $\overline{X} \pm W\sqrt{S^2/n}$ ") and on the number of data samples n used to compute $\overline{X}$ and S. For large $n\,(\geq 30)$, W is known as the *z statistic* and at the 95% confidence level, W approaches 1.960, meaning that $\pm 1.960\,\sigma/\sqrt{n}$ contains 95% of the whole data population under a bell-shaped distribution curve – that's why we say " 2 sigma is about a 95% confidence level " (because 2 is about the same as 1.960). For small n (2 to about 30), W is known as the *t statistic*: the Student *t* test. For $n = 2$, $W = 12.706$, far larger than 1.960, so you are at best confident that the very large span, $\pm 12.706\sigma/\sqrt{2}$ contains 95% of the population (i.e, you don't know much).

For Case I, if you are in the middle of Test 1, and Test 1 contains many data points $(I > 30)$, you can be 95% confident that the next, $I+1th$, data point would be within about $\mu_1 \pm 2\sqrt{\sigma_1^2/I}$. However, that doesn't tell you a thing about the expectations for Test 2 and 3. Tests 2 and 3 do tell you that a fourth test should have a mean within about $\overline{\mu} \pm W\sqrt{\sigma_\mu^2/J}$ (where $W = 3.182$ for $J = 4$ tests). Certainly, the factor $3.182/\sqrt{4} > 1.960/\sqrt{30}$ (your knowledge of the location of μ has decreased fourfold now that you are taking test-to-test variations into consideration, even if by coincidence σ_μ^2 were to equal σ_1^2).

For Case II, the large σ_j^2 guarantee that the 95% confidence interval is large during any test j, and the remaining tests do nothing to dispel your lack of confidence because, don't forget, variance are uncertainties in μ.

For both Cases I and II, lots more data is needed to close the desired confidence interval.

For Case III, Tests 2 and 3 define a small confidence interval: it would be statistically difficult to expect a Test 4 to produce significantly different results.

The variances in Equation 1 gain meaning for both Cases I and II. σ_n^2 is large and more data is called for (more tests in the instance of Case I, more date per test in the instance of Case II). For Case III, σ_n^2 is small and – statistically – more data per test or more tests are not called for; this would indicate that the next hierarchy of testing, namely testing K different test items (if available), is ready to be embarked on. Thus, the magnitude of σ_n^2 indicates a correlation with the need for more data, but σ_μ^2 and $\overline{\sigma^2}$ tell you where the " more data" is required; and they are the variances which should be looked at for a proper balance of I, J, and K in generating "confidence".

The word "statistically" is underlined above for two reasons: (1) usually, we have one test item available (K = 1), so we can only infer population performance, and (2) Mother Nature does what she wants, not what we want; the next data point $I+1$ or the next test $J+1$ or the next test item $K+1$ could produce totally different results.

How do we resolve this? Certainly not through statistics alone, which are attuned to Mother Nature only through generalized assumptions which may only peripherally relate to the physics of test items. The question can be statistically addressed through assumptions and guesses about independence of the $i\text{th}$ data point on the $i-1\text{th}$, of the $j\text{th}$ test on the $j-1\text{th}$, and the $k\text{th}$ test item on the $k-1\text{th}$. There exist rigorous methods to accommodate this but very quickly the assumptions and guesses compound to produce mostly speculation, and speculation gets us into trouble. The answer, incontrovertibly, is data and data is the only link between statistics, Mother Nature and politics.

It is true as shown in Appendix B that, for $J=6$ tests and 2.571 is the *t statistics* for 6 samples, $\overline{X} \pm W\sqrt{S^2/J} = 1.050S \approx 1S$. The assumed significance is that 6 tests give you μ within $\overline{X} \pm 1S$ at the 95% confidence level and don't cost too much. There is nothing sacred about $1S$ or 95% - these are simply easy-to-digest values accepted by the T&E community; the entire confidence curve resembles an exponential (Appendix B) indicating 3 test confidence minimum.

Probably more valid is the "proper balance of I, J, and K" referred to earlier. Equation 1 can be cascaded forward to accommodate the impact of different test items

K, different product lots L, and different scenarios M. It can also be cascaded backwards for the impact of variations in the performance of components, software, etc. Since σ_n^2 is always a function of σ_μ^2 and $\overline{\sigma^2}$, the largest of σ_μ^2 and $\overline{\sigma^2}$ dominates, and that is the one that needs to be reduced, either through more data points per test, or through more tests, or more test items, etc.

It is not valid, therefore, to say that many data points over one test (which covers the spectrum of I very well) covers the J spectrum (results of different tests) at all: I, J, K, L, and M may be(we don't know until we test) mutually exclusive.

Conclusion.

This bring us to, "how many tests should we do?" Obviously, more than one, or Equation 1 can't be analyzed. A six test series has nice numbers such a 1, 95, and 6 (1σ, 95%, and 6 tests) and is thus simplistically, probabilistically, and fiscally palatable. But if these tests produce results that look like Case I and II, we haven't determined much. If we have control, we should, by testing, establish the correct values of I, J, etc to minimize σ_n^2.

APPENDIX A

Assume that a test is conducted yielding some performance parameter μ with variance σ^2 from I data points x. Using the definition for σ^2 and μ

$$\sigma^2 = \frac{1}{I}\sum_i (x_i - \mu)^2, \qquad \textit{Equation A-1}$$

$$\mu = \frac{1}{I}\sum_i x_i \qquad \textit{Equation A-2}$$

and expanding Equation A-1 with Equation A-2 substitution generates

$$\begin{aligned}\sigma^2 &= \frac{1}{I}\sum_i x_i^2 - \frac{2}{I}\mu\sum_i x_i + \frac{1}{I}\sum_i \mu^2 \\ &= \frac{1}{I}\sum_i x_i^2 - 2\mu\cdot\mu + \frac{1}{I}I\mu^2 \qquad \textit{Equation A-3} \\ &= \frac{1}{I}\sum_i x_i^2 - \mu^2\end{aligned}$$

which is a restatement of Equation A-1. The use of I instead of $I-1$ in the denominator of Equation A-1 and A-2 is entirely valid for large I ,which simplifies the algebra, and does not detract from the goal of this appendix.

A set of J tests consisting (for further algebraic simplification) of I data points x_{ij} (the j subscript is added to the x_i of Equation A-1 and A-2 to identify which test) produces J sets of μ_j with associated σ_j^2 where

$$\mu_j = \frac{1}{I}\sum_i x_{ij} \qquad \textit{Equation A-4}$$

$$\sigma_j^2 = \frac{1}{I}\sum_i x_{ij}^2 - \mu_j^2 \qquad \textit{Equation A-5}$$

The average $\overline{\mu}$, of the μ_j , and the associated variance σ_μ^2 of $\overline{\mu}$ are

$$\overline{\mu} = \frac{1}{J}\sum_j \mu_j \qquad \textit{Equation A-6}$$

$$\sigma_\mu^2 = \frac{1}{J}\sum_j \mu_j^2 - \overline{\mu}^2 \qquad \textit{Equation A-7}$$

The mean μ_n and associated variance σ_n^2 using all $n = IJ$ data points x_{ij} in one group are

$$\mu_n = \frac{1}{IJ}\sum_{i,j} x_{ij} = \overline{\mu} \qquad \textit{Equation A-8}$$

$$\sigma_n^2 = \frac{1}{IJ}\sum_{i,j} x_{ij}^2 - \overline{\mu}^{\,2} \qquad \textit{Equation A-9}$$

The simple average of the J variances σ_j^2 obtained from each test is

$$\begin{aligned}\overline{\sigma^2} &= \frac{1}{J}\sum_j \sigma_j^2 \\ &= \frac{1}{J}\sum_j \left(\frac{1}{I}\sum_i x_{ij}^2 - \mu_j^2\right) \\ &= \frac{1}{IJ}\sum_{i,j} x_{ij}^2 - \frac{1}{J}\sum_j \mu_j^2\end{aligned} \qquad \textit{Equation A-10}$$

Solving for σ_μ^2 , σ_n^2, and $\overline{\sigma^2}$ as functions of each other, from Equation A-7, A-9 and A-10 yields

$$\overline{\sigma^2} = (\sigma_n^2 + \overline{\mu}^2) - (\sigma_\mu^2 + \overline{\mu}^2)$$

$$\underline{\sigma_n^2 = \sigma_\mu^2 + \overline{\sigma^2}} \qquad \textit{Equation A-11}$$

APPENDIX B

$$\mu = \bar{X} \pm W\sqrt{\frac{S^2}{J}}$$

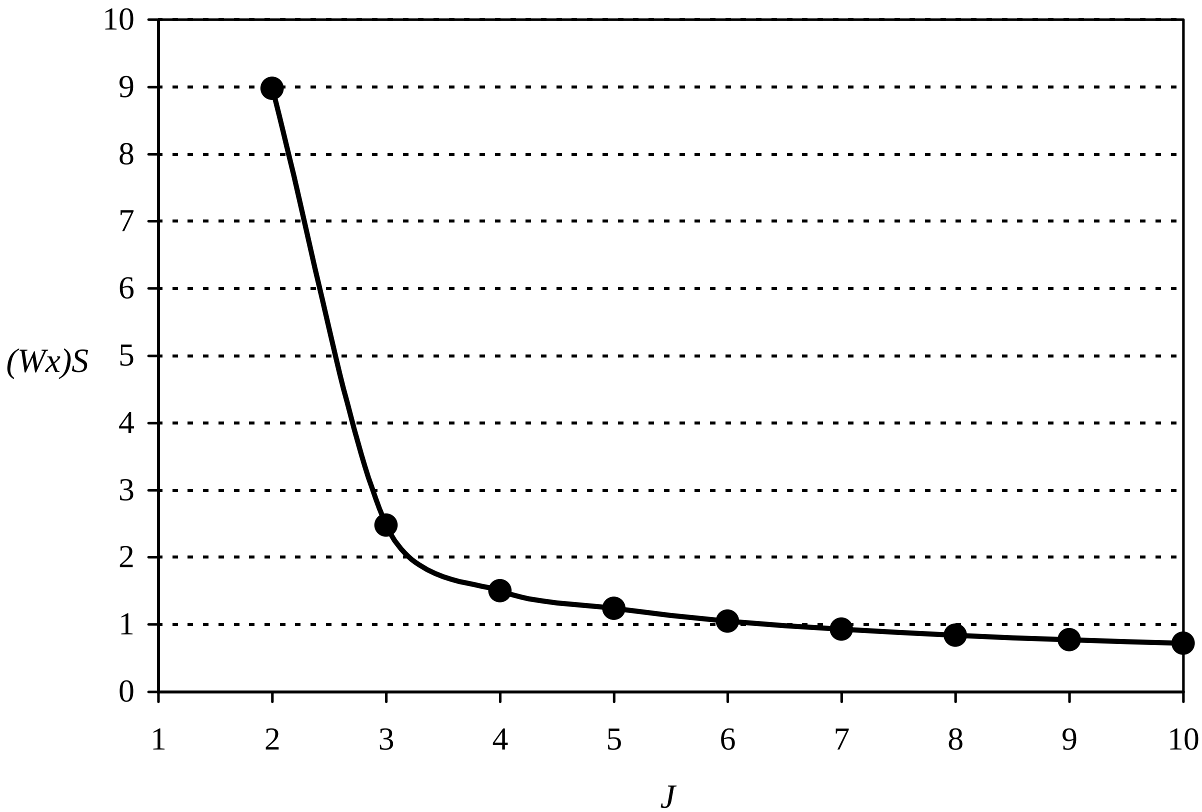
Assume:

$\bar{X} = 0$

$W = 95\%$ Level of Certainty

$J =$ Number of Tests

$$\mu = \left(\pm W\sqrt{\frac{1}{J}} \right) S = (Wx)S$$



ANNEX C TO GLOBAL POSITIONING SYSTEM

CORE TEST PLAN

Example Simulator Scenarios

Example Simulator Scenarios

This Annex provides three examples of simulator scenarios applicable to select GPS testing. The inclusion of these scenarios in this document is not meant to imply that their use is directed by any agency, but they are provided for information and as examples only. The three following scenarios were derived by capturing actual vehicle dynamics from field tests. The vehicle dynamic data was “thinned” to a 1Hz data rate to be appropriate for use in GPS simulators. The three scenarios represent low, medium, and high dynamic missions, and were captured from a land-mobile vehicle (van), a cargo/utility aircraft, and a fighter/trainer aircraft, respectively.

The plots of these scenarios are provided on the following pages. The data files defining these scenarios are available on the Internet as follows:

Go to http://www.gpstestcoe.com
Click on GPS Bulletin Board Site link
Click on GPS Reference Documents
Click on the appropriate document/file

(Note: A major revision to this website is currently in progress, and more intuitive links to these and many other documents will be apparent after completing the first step, above.)

Almanac and ephemeris data files appropriate to execute these simulator missions at selected geographical locations are also provided at this web location.

The decision to use these or any other simulator scenarios should be made by the test director on the basis of the design of the GPS receiver being tested, and the purpose and objectives of the test program.

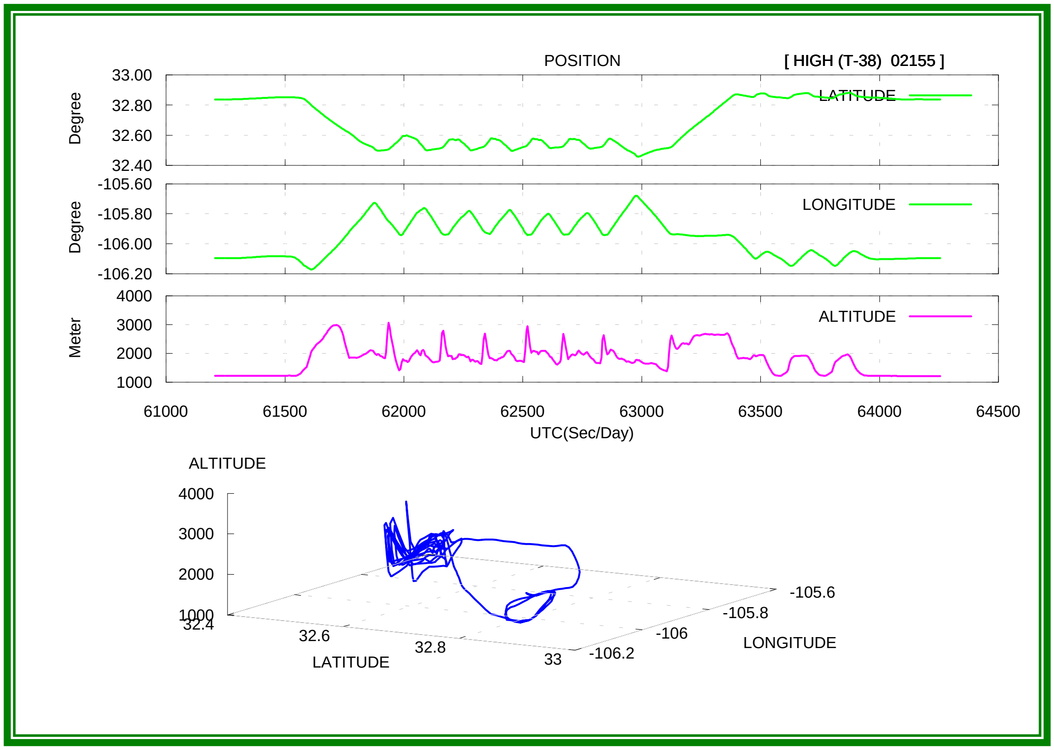


Figure1. High Dynamics Position

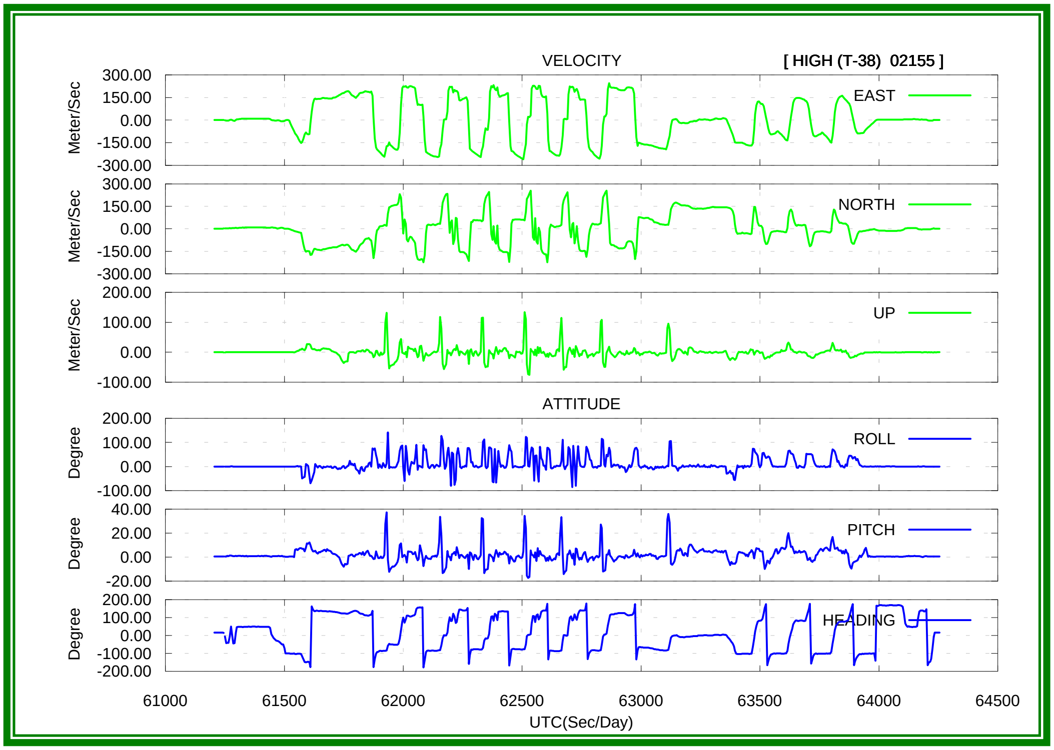


Figure 2. High Dynamics Velocity and Attitude

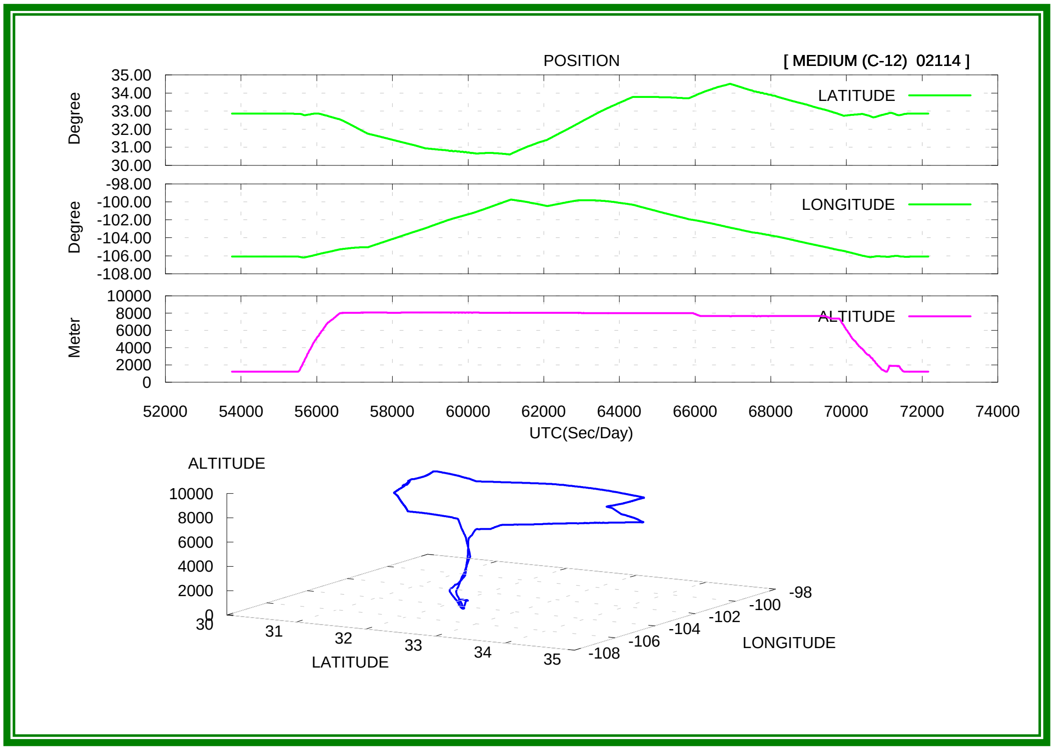


Figure 3. Medium Dynamics Position

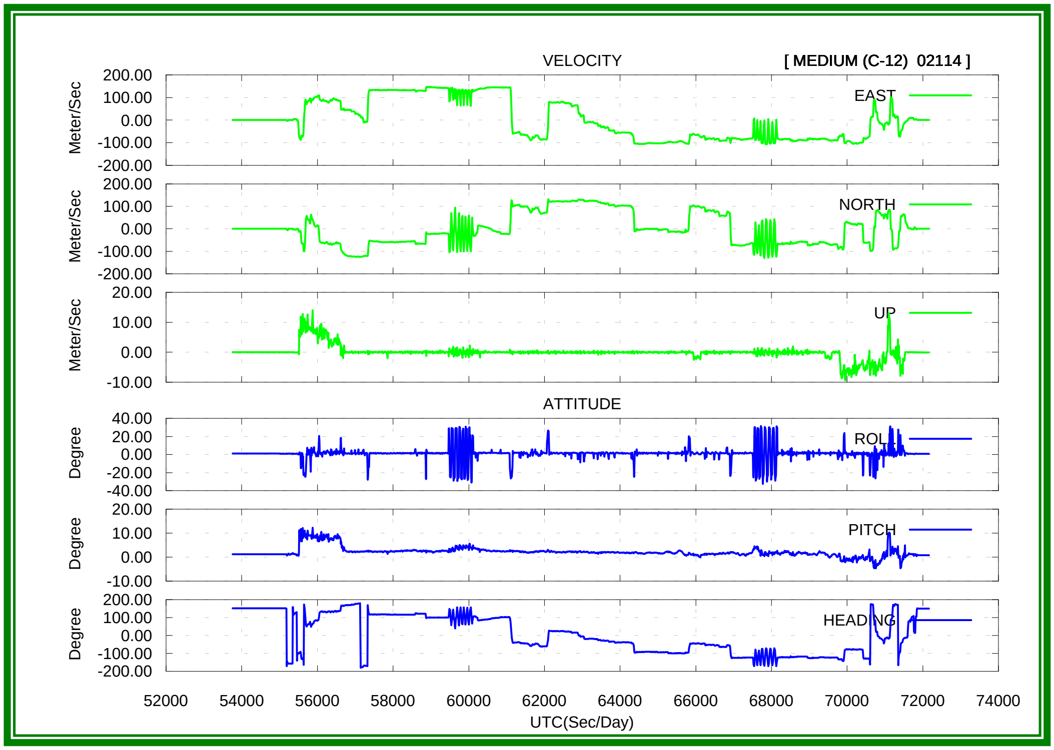


Figure 4. Medium Dynamics Velocity and Attitude

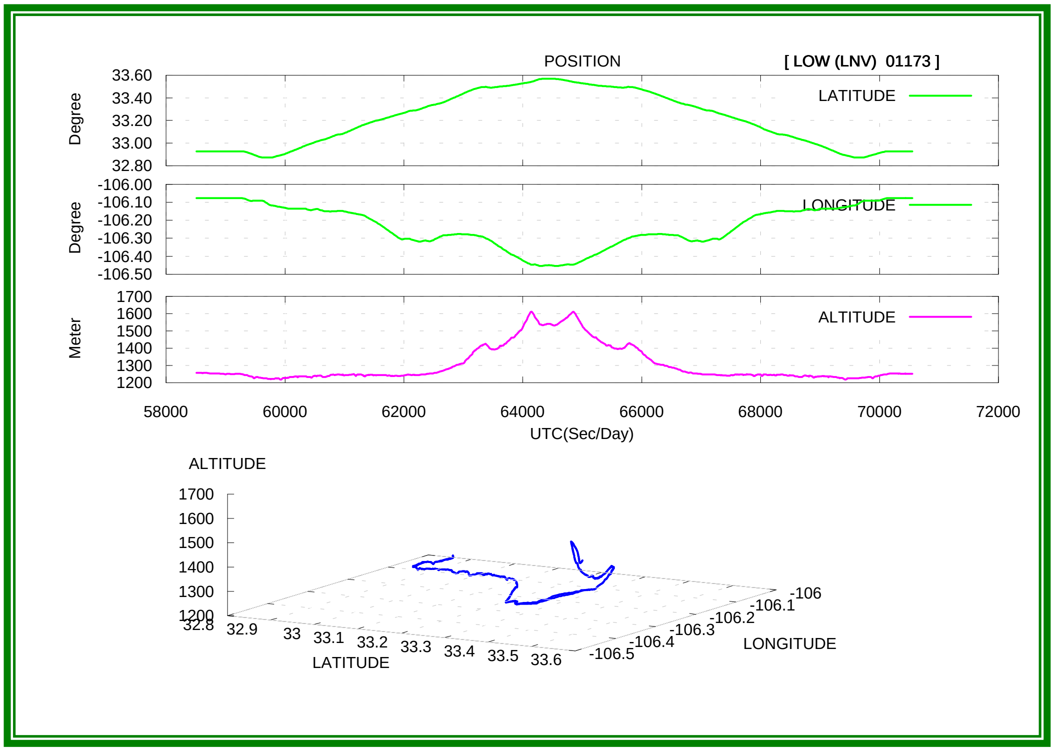


Figure 5. Low Dynamics Position

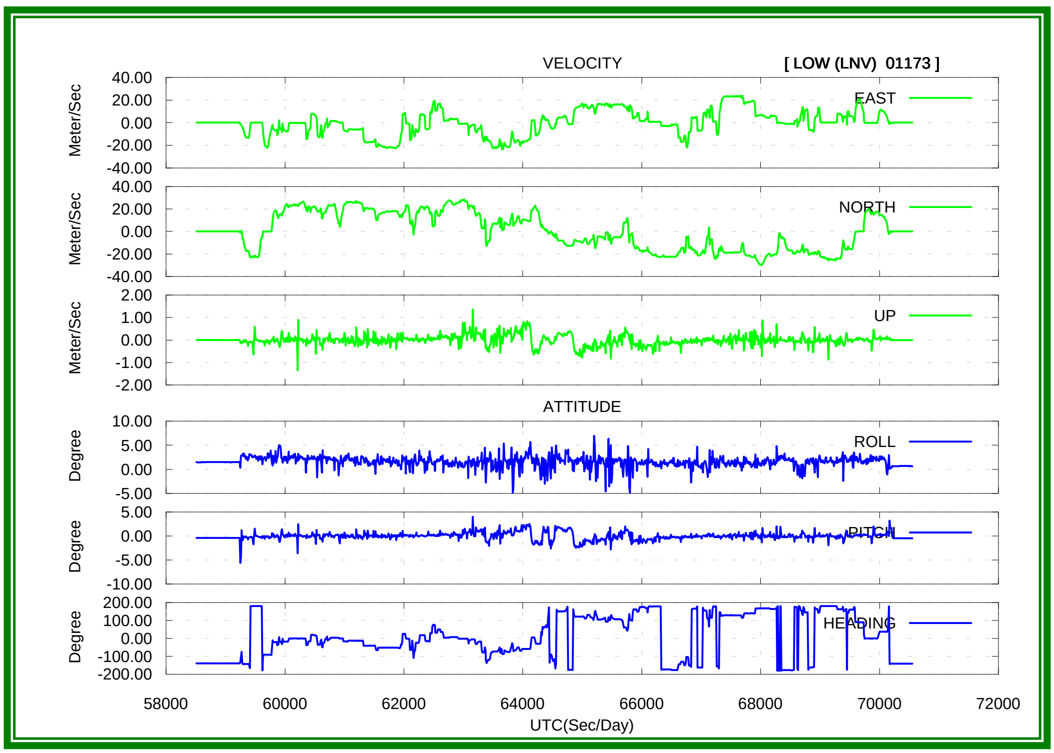


Figure 6. Low Dynamics Velocity and Attitude